obstructive pulmonary disease (COPD) and ischemic heart disease, thus, surgical resection can be difficult in such cases. Also, 20–30% of central type early stage lung cancer (CELC) are multicentric [5] and treatment preserving pulmonary function should be considered.

An annual mass screening program for lung cancer has been conducted since 1982 in Japan, including annual chest X-ray examinations for those aged 40 or over, and added sputum cytology for individuals aged 50 or over with a smoking history of over 30 pack-years and those aged 40 or over with a history of bloody sputum within the previous 6 months. For individuals suspected to have lung cancer on chest X-ray or sputum cytology, further examinations were performed to confirm the diagnosis [6–8].

Advances in bronchoscopy and the increasing prevalence of sputum cytology have helped to increase the detection of CELC [9]. Surgery is considered to be a curative treatment method for CELC, but it might be wasteful by sacrificing a large volume of lung parenchyma to treat only a 1–2 cm superficial lesion of a large bronchus. The first clinical endoscopic photodynamic therapy (PDT) for CELC was performed in 1980 and PDT has been employed to treat CELC with curative intent up to the present [10–13].

The objective selection of the lesions for PDT is important in terms of the tumor extent on the bronchial mucosa as well as the depth of invasion to the bronchial wall [13]. The penetration of laser light used for PDT is limited, therefore, the lesions should be limited to within the cartilagenous layer of the bronchial wall for curative PDT. For this reason, the meticulous observation of bronchial mucosa by a combination of conventional bronchoscopy and newly developed imaging techniques is necessary to determine the indications of PDT [14]. PDT has become the first treatment for selected CELC since the criteria for the indications of PDT were established.

MATERIALS AND METHODS

PubMed was searched using the medical subject headings (MeSH) for "lung cancer" and "PDT" (through February 2011). A total of 293 articles were found and clinical papers with analysis of outcomes of survival or response rate were selected and carefully reviewed.

RESULTS

Selection of CELC Suitable for PDT

The Japan Lung Cancer Society defined the bronchoscopic criteria of CELC as follows [15];

- Location in subsegmental or more proximal bronchi.
- The peripheral margin of the tumor is recognizable bronchoscopically.
- The tumor size is less than 2 cm in greatest dimension.
- Squamous cell carcinoma is proven histologically.

CELC is classified into three categories according to the endoscopic apperances, early polypoid type, nodular type, and flat type.

Previous studies showed that there was a correlation between the tumor features and the depth of bronchial invasion. Protruding type tumors tended to invade deeper than superficially spreading type tumors. In particular, over 90% of tumors classified as flat type and under 10 mm in maximum dimension were carcinoma *in situ*. These results demonstrated that a flat lesion, when the diameter is less than 10 mm and the distal margin is visible, could be an excellent indication for endoscopic treatment [16,17]. These judgements require expertise, however, advances in medical science may also contribute to better performance in the diagnosis and management of CELC.

Autofluorescence bronchoscopy (AFB) has been widely employed to capture the subtle abnormal findings of bronchial mucosa which sometimes cannot be detected by conventional bronchoscopy [18–24]. AFB is based on the principle that the normal bronchial tissue emits green autofluorescence (500–600 nm) excited by blue light, while malignant tissue lacks green autofluorescence. Abnormal sites can be discriminated from normal areas by enhancing the difference in intensity of green autofluorescence [18,22]. AFB has been reported to show higher sensitivity for carcinoma *in situ* and dysplasia and to contribute to the objective diagnosis of tumor extent on the bronchial surface [18–24].

The accurate evaluation of the depth of bronchial invasion of the tumor is another important issue to decide the indications of PDT because if the tumor invades beyond the cartilaginous layer, PDT should not be applied due to the limited light penetration, and surgery should be selected instead [14,25]. Endobronchial ultrasonography (EBUS) has been reported to be useful in the precise observation of the layered structure of the bronchial wall, and previous reports showed that the evaluation of degree of intrabronchial invasion by EBUS is superior compared to speculation based on the interpretation of the endoscopic appearance of tumor [25–29]. Kurimoto et al. demonstrated that EBUS was useful to determine the depth of tumor invasion into the bronchial wall, and the accuracy of EBUS from the histopathologic findings was 95.8%. The 20 MHz EBUS image shows five layers in the cartilaginous portion of bronchial wall. The third to fifth layers are images of cartilage. Therefore, it is feasible to evaluate the depth of invasion using EBUS and determine whether or not the tumor invades into or beyond the cartilaginous layer [26]. In lesions with an intact third layer on EBUS, complete response (CR) can be achieved with PDT. Takahashi et al. [29] performed EBUS to evaluate the degree of carcinoma invasion into the bronchial wall in 22 lesions suspected of CELC before treatment. Fourteen lesions were diagnosed to be intracartilagenous lesions, and the remaining 8 lesions, extracartilagenous lesions, respectively. Among the 14 intracartilagenous lesions, 10 lesions were treated by PDT and complete remission was obtained in 9. The remaining 4 lesions were surgically resected and pathological examination of resected lungs revealed that invasion did not reach the cartilaginous layer in 3. Of 8 lesions diagnosed to be extracartilagenous, 4 cases received surgery and pathology revealed that EBUS diagnosis was correct in 3 and overestimated in 1.

PDT for CELC

PDT with photofrin. Phase II clinical trials using Photofrin for early stage lung cancer were conducted from June of 1989 to March of 1992. In the studies, a total of 61 CELCs (51 patients) were registered and treated using Photofrin (2.0 mg/kg) and 630-nm laser light illumination of 100–200 J/cm^2 [30]. Of 59 assessable CELCs, CR was obtained in 50 (84.8%), 6 had partial response, and 3 had no response. This study demonstrated that the length of longitudinal tumor extension on the bronchial surface was strongly related to the therapeutic outcome. Out of 45 CELCs 1 cm or less, CR was obtained in 44 (97.8%), on the contrary, among 14 CELCs that had a longitudinal extension greater than 1 cm, only 6 (42.9%) showed CR after PDT. The Japanese government approved PDT for lung cancer using Photofrin in October 1994, and authorized reimbursement through the National Health Insurance began in 1996. In 1995, the U.S. Food and Drug Administration (FDA) approved Photofrin for esophageal cancer, and in 1998, it was approved for the treatment of early lung cancer [31,32]. Kato reported the consecutive clinical data of PDT with Photofrin for CELC from1980 to 2005 in a single institute (Tokyo Medical University). This showed that CR was obtained in 224 (84.8%) out of the 264 lesions. The treatment outcome was analyzed based on the size of the lesions. The lesions were classified into four groups according to the maximum dimension on the longitudinal axis, as follows: <0.5 cm (56 lesions); 0.5–0.9 cm (124 lesions); 1.0–2.0 cm (50 lesions); and >2.0 cm (34 lesions). The CR rates of the first two groups were 94.6% and 93.5%, respectively. However, the CR rates of lesions from 1.0 to 2.0 cm was 80%, >2.0 cm, and 44.1%, respectively. CELCs less than 1 cm in diameter showed a favorable cure rate by PDT, thus this is a good standard to decide the indications of PDT [31].

PDT with the NPe6 second-generation photosensitizer. Among the second-generation photosensitizers, NPe6 is considered to be a promising photosensitizer and has shown both antitumor efficacy in a murine tumor model and rapid clearance from skin [33]. We postulated that since NPe6 has a longer absorption band (664 nm) than that of Photofrin (630 nm), PDT using NPe6 would have greater photodynamic efficacy due to a slight gain in the penetration depth of light than that with Photofrin. A phase II clinical study was conducted from 1997 to 2000 to investigate antitumor effects on CELC as well as the safety of the new generartion photosensitizer mono-L-aspartyl chlorine e6 (taraporfin sodium, NPe6) in combination with the diode laser [33]. Laser irradiation (100 J/cm^2) using a diode laser was performed 4 hours after administration of NPe6 (40 mg/m^2). A total of 45 CELCs (40 patients) were collected. CR was obtained in 84.6% of lesions (82.9% of patients). Skin photosensitivity was reported to be much lower than with photofrin and the disappearance of skin photosensitivity was recognized in 28 of 33 patients (84.8%) within 2 weeks after administration. NPe6 was approved for the treatment of CELC by Japanese Ministry of Health, Labor, and Welfare in 2004 and also for advanced lung cancer in 2010 [34].

Between June 2004 and December 2008, a total of 91 consecutive CELCs (75 patients) were treated by PDT using NPe6 in Tokyo Medical University and CR was obtained in 85 lesions (CR rate 93.4%). Of the 91 lesions examined in this study, 70 had a diameter of ≤1.0 cm and the rest of the 21 cancer lesions were >1.0 cm in size. The CR rate of CELC ≤1.0 cm in diameter was 94% (66/70) and for those >1.0 cm in diameter, 90.4% (19/21), respectively. This early result suggests that PDT with NPe6 has a stronger antitumor effect than Photofrin, therefore, similar treatment outcome even for large tumors >1.0 cm in diameter should be possible [34]. The CR ratio is shown according to the tumor size in Table 1.

State-of-the-art. In addition to advances in photosensitizer, precise evaluation and sophisticated treatment technique for CELC might improve the treatment outcome of PDT [35].

Our routine clinical process for PDT in CELC is divided into four phases: evaluation phase, photodynamic diagnosis (PDD) phase, PDT phase, and confirmation phase.

Evaluation phase. As already described, AFB and EBUS are routinely performed to evaluate the extent and the depth of CELC lesions to decide the indications for PDT.

PDD phase. Just before PDT, we perform PDD using an AFB system (SAFE-3000, Hoya Co., Tokyo, Japan). SAFE-3000, equipped with a diode laser (408 nm) can excite NPe6 and capture the red fluorescence emitted from the tumor enhanced by NPe6. The PDD technique is useful in the final determination of the area of laser illumination because it clearly reveals the tumor margin.

PDT phase. During PDT, the shutter speed of the image capture of the videoendoscope (SAFE 3000) is

TABLE 1. CR Rate According to Tumor Diameter

	Furuse et al. [30]	Kato [33]	Usuda [34]
No. of cases	59	264	91
Photosensitizer	Photofrin	Photofrin (NPe6 in 16)	Npe6
CR rate and tumor size			
1.0 cm≤	97.8%	93.9%	94.0%
1.0–2.0 cm	50.0%	80.0%	90.4%
>2.0 cm	37.5%	44.1%	NA

changed to the fastest mode to reduce capture of scattered laser light, which helps to observe the real time monitoring confirming that the laser light from the tip of the probe is correctly illuminating the target.

Confirmation phase. Immediately after the PDT phase, PDD using the SAFE-3000 system is again performed to confirm the loss of red fluorescence emitted from the tumor and that a sufficient dose of laser illumination is given. This procedure confirms that all the NPe6 in the tumor had been excited by the laser irradiation, resulting in the red fluorescence of the tumor no longer being able to be observed. If red fluorescence is observed, additional laser irradiation is necessary. The representative treatment process is shown in Figure 1.

These four processes enable us to determine the indication of PDT and provide the correct information of the area to treat as well as determine the optimal dose of laser illumination. The present procedure should be effective to minimize the possibility of local recurrence after PDT.

DISCUSSION

PDT is not indicated in all CELCs. Precise evaluation of the lesion for the indication of PDT is one of the important key issues successful treatment. PDT for CELC was initiated in 1980 in our institution, and the indications of PDT have become increasingly reliable based on the accumulation of clinical experiences. Lesions less than 1 cm in maximal dimension are considered to be good indications for PDT and favorable treatment outcome has been obtained [10–13,30–34]. Konaka et al. [16] analyzed resected cases of CELC and reported that the greatest tumor dimension strongly correlated with the depth of intrabronchial invasion of the tumor, and that polypoid type or nodular type tumors tended to invade deeper than superficially spreading type tumors.

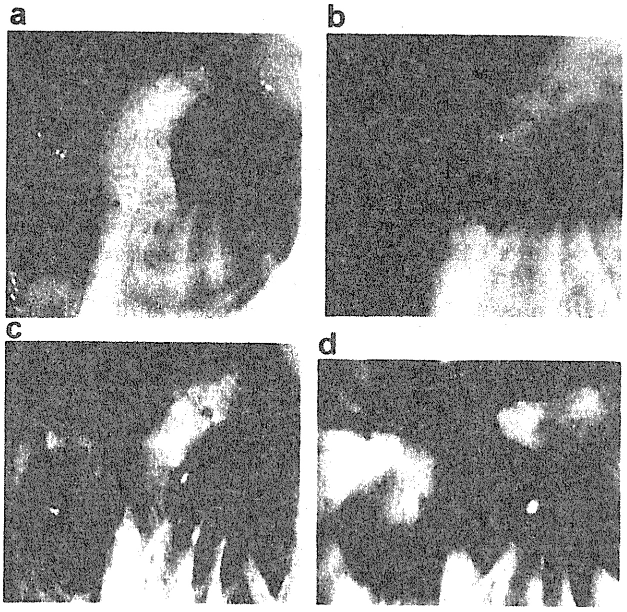

Fig. 1. Central type early stage lung cancer (Flat type) in right upper lobe bronchus. (a) Videoendoscopy, (b) autofluorescence bronchoscopy, and (c) photodynamic diagnosis before PDT (PDD phase). The red fluorescence emitted from the tumor enhanced by NPe6 can be observed. (d) Confirmation phase. All the NPe6 in the tumor was excited by the laser irradiation, resulting in the red fluorescence of the tumor no longer being able to be observed.

Akaogi et al. [17] analyzed the endoscopic and pathology features of CELC and reported that polypoid or nodular lesions less than 10 mm and flat lesions up to 15 mm were all within the cartilaginous layer and showed no nodal metastasis. In particular, over 90% of their tumors classified as the flat type and under 10 mm in maximum dimension were carcinoma *in situ*. Comprehensive evaluation for CELC using AFB and EBUS enables us to evaluate the extent and depth of tumor invasion and to select the optimal treatment modality. Bronchoscopic optical coherence tomography (OCT) will be widely applied in the near future [14,36,37]. Our early experience has revealed that endoscopic OCT examination provides high-resolution images of the bronchial surface, making possible detailed examination of intraepithelial lesions. Since the structures observed in this system are the boundaries between tissue layers, layers between epithelium and basement membrane were clearly demonstrated, which is helpful to evaluate the depth of invasion of bronchial tumors [36].

In addition to new diagnostic modalities, recent advances in PDT-related procedures, especially in the PDD phase and dose evaluation phase may contribute to more sophisticated endoscopic PDT for CELC [35].

The most recent generation photosensitizer, NPe6 seems to have stronger antitumor effects than Photofrin, but with reduced adverse reactions [33,34]. Another reason for the superior antitumor effect of NPe6 might be explained by molecular analysis. The expression of Breast Cancer Resistant Protein (BCRP) significantly negatively affected the efficacy of Photofrin but NPe6 exhibited antitumor effect, regardless of the expression status of BCRP [38]. Usuda et al. [34] reported that there was no significant difference in local control after CR between CELCs $\leq$1.0 cm in diameter and those $>$1.0 cm. These results suggest that PDT with NPe6 may have a similar treatment outcome regardless of tumor size, as long sufficient laser illumination of the entire tumor is possible.

The present guidelines of PDT for CELC were established based on the data in the previous era; bronchoscopists decided on the indications of PDT solely using white light bronchoscopy and performed PDT with Photofrin. We postulate that more comprehensive diagnostic techniques and new generation photosensitizers may increase the CR rate and expand the indications of PDT for larger tumors.

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CLINICAL INVESTIGATION **Education and Training**

NATIONAL MEDICAL CARE SYSTEM MAY IMPEDE FOSTERING OF TRUE SPECIALIZATION OF RADIATION ONCOLOGISTS: STUDY BASED ON STRUCTURE SURVEY IN JAPAN

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Purpose: To evaluate the actual work environment of radiation oncologists (ROs) in Japan in terms of working pattern, patient load, and quality of cancer care based on the relative time spent on patient care.
Methods and Materials: In 2008, the Japanese Society of Therapeutic Radiology and Oncology produced a questionnaire for a national structure survey of radiation oncology in 2007. Data for full-time ROs were crosschecked with data for part-time ROs by using their identification data. Data of 954 ROs were analyzed. The relative practice index for patients was calculated as the relative value of care time per patient on the basis of Japanese Blue Book guidelines (200 patients per RO).
Results: The working patterns of RO varied widely among facility categories. ROs working mainly at university hospitals treated 189.2 patients per year on average, with those working in university hospitals and their affiliated facilities treating 249.1 and those working in university hospitals only treating 144.0 patients per year on average. The corresponding data were 256.6 for cancer centers and 176.6 for other facilities. Geographically, the mean annual number of patients per RO per quarter was significantly associated with population size, varying from 143.1 to 203.4 ($p < 0.0001$). There were also significant differences in the average practice index for patients by ROs working mainly in university hospitals between those in main and affiliated facilities (1.07 vs 0.71: $p < 0.0001$).
Conclusions: ROs working in university hospitals and their affiliated facilities treated more patients than the other ROs. In terms of patient care time only, the quality of cancer care in affiliated facilities might be worse than that in university hospitals. Under the current national medical system, working patterns of ROs of academic facilities in Japan appear to be problematic for fostering true specialization of radiation oncologists. © 2012 Elsevier Inc.

Structure survey, Working pattern, Patient load, Quality of cancer care, Medical care system.

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Conflict of interest: none

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INTRODUCTION

The medical care systems of the United States and Japan are very different, which influences the personnel cost of medical staff. In radiation oncology, too, there is thus a major difference in personnel distribution between the United States and Japan. Most radiotherapy facilities in the United States are supported by full-time radiation oncologists (ROs), whereas the majority of radiotherapy facilities in Japan still rely on part-time ROs. Radiotherapy facilities with less than one full-time equivalent (FTE) RO on their staff still account for 56% nationwide (1). The Cancer Control Act was implemented in Japan in 2007 in response to patients' urgent petitions to the government (2). This act strongly advocates the promotion of radiotherapy (RT) and an increase in the number of ROs and medical physicists. However, a shortage of ROs still remains a major concern in Japan and will remain so for the foreseeable future.

The Japanese Society of Therapeutic Radiology and Oncology (JASTRO) has conducted national structure surveys of RT facilities in Japan every 2 years since 1990 (1, 3). 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 RT.

In this study, we used the data of the JASTRO structure survey of 2007 to evaluate the actual work environment of radiation oncologists in Japan in terms of working pattern, patient load, and the quality of cancer care based on the relative time spent on patient care.

MATERIALS AND METHODS

Between March and December 2008, JASTRO carried out a national structure survey of radiation oncology in the form of a questionnaire in 2007 (1). The questionnaire consisted of questions about 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. The response rate was 721 of 765 (94.2%) from all actual RT facilities in Japan.

Table 1 shows the overview of radiation oncology in Japan. University hospitals accounted for 15.8% of all RT facilities and had 40.0% of the total full-time ROs and treated 29.5% of all patients. The corresponding data were 4.0%, 7.8%, and 10.2% for cancer centers, and 80.2%, 52.2%, and 60.3% for other RT hospitals, respectively. "Full-time/part-time" indicates the employment pattern of RO. In Japan, even full-time ROs must work part-time in smaller facilities such as other RT hospitals. We considered these numbers to be inappropriate for accurate assessment of personnel. For this survey, we therefore collected FTE (40 h/week for radiation oncology services only) data depending on hours worked in clinical RT of each RO. For example, if an RO works 3 days at a university hospital and 2 days at an affiliated hospital each week, FTE of the RO at the university hospital is 0.6 and at an affiliated hospital it is 0.4. The FTE of a facility that has three ROs with 0.8, 0.4, and 0.6 is calculated as 1.8 in total.

This survey collected the work situation data of a total of 1,007 full-time ROs and 534 part-time ROs. The data of full-time ROs were crosschecked with those of part-time ROs by using their identification data. Table 2 shows the result of crosschecking between data of full-time ROs and data of part-time ROs. In this study, data of 954 ROs were analyzed. Table 3 shows an overview of the analyzed data. In ROs working mainly in university hospitals, there are two ROs who worked at a maximum of six facilities (main facilities and five affiliated facilities) SAS 8.02 (SAS Institute Inc., Cary, NC) (4) was used for the statistical analysis, and the statistical significance was tested by means of the Student's t-test or analysis of variance.

The Japanese Blue Book guidelines (5, 6) for structure of radiation oncology in Japan based on Patterns of Care Study (PCS) data were used as the standard for comparison with the results of this study. PCS in Japan have been used since 1996 and have disclosed significant differences in the quality of RT by the type of facilities and their caseloads (7, 8). The standard guidelines for annual patient load per FTE RO have been set at 200 (warning level 300).

To evaluate quality of cancer care provided by ROs, the relative practice index for patients was calculated by the following expression.

$$\frac{\sum_{k=1}^{n} f_k}{\sum_{k=1}^{n} a_k} \times 200$$

in which n is the number of facilities that the RO works in ($n = 1, 2, 3, \ldots, k$), f_k is the FTE of the RO in facility k, and a_k is the annual number of patients per RO in facility k

Calculation method of coefficient "200:"

1) Number of weeks per year = (365–15)/7 = 50 weeks
   ※ Japan has 15 national holidays a year
2) 1.0 FTE = 40 h/week
3) Annual working hours of FTE 1.0 = 50 × 40 h = 2,000 h
4) Relative practice index for patients was normalized using the Blue Book guideline of 200 patients/FTE RO. For this guideline, care time per patient was set at 10 hours (2,000 h/200 patients).
5) Coefficient was 200 (2000/10).

RESULTS

Working patterns

Figure 1 shows working patterns of ROs working mainly in (a) university hospitals, (b) cancer centers, and (c) other

Table 1. Categorization of radiotherapy facilities in Japan

Facility category	Number of facilities	New patients	Total patients (new + repeat)	Full-time ROs n	Full-time ROs FTE	Part-time ROs n	Part-time ROs FTE
University hospital	114	50,351	60,555	403	293.0	70	21.6
Cancer center	29	16,794	20,968	78	73.7	14	2.5
Other radiotherapy hospital	578	103,084	123,564	526	351.8	450	83.7
Total	721	170,229	205,087	1,007	718.5	534	107.8

Abbreviations: RO = radiation oncologist; FTE = full-time equivalent (40 hours per week for radiation oncology services only).

Table 2. Connection between full-time and part-time RO data

Data of full-time ROs	
Total number	1,007
Number of full-time ROs excluded from this analysis*	53
Number of full-time ROs analyzed	954
Breakdown	
Number of ROs who worked as full-time staff at main facilities and as part-time staff at affiliated facilities	199
Number of ROs who conducted only radiotherapy-related work as full-time staff at individual facilities (FTE of the RO was 1.0)	275
Number of ROs who conducted radiotherapy-related and other work as full-time staff at individual facilities (FTE of the RO was less than 1.0)	480
Data of part-time ROs including duplicate ROs	
Total number	534
Number of ROs who worked as full-time staff at main facilities and as part-time staff at affiliated facilities (number of part-time ROs analyzed)	280
Number of ROs who worked as only part-time staff at the facilities (Number of part-time ROs excluded from this analysis)	254

Abbreviations: RO = radiation oncologist; FTE = full-time equivalent (40 hours per week for radiation oncology service only).

* Data of full-time ROs who worked at facilities with few patients were excluded, as were duplicated data of full-time ROs.

RT hospitals. The percentages of white parts in Figures 1 (a-c) were 17.4%, 5.0%, and 32.0%.

In university hospitals, the mean FTE RO for main facilities was 0.73 and for affiliated facilities it was 0.10. The corresponding figures were 0.94 and 0.01 for cancer centers, and 0.67 and 0.01 for other RT hospitals. For university hospitals, the ratio of ROs working only in main facilities was 16.4%, and the corresponding figures for cancer centers and other RT hospitals were 79.5% and 31.7%, respectively. The ratio of ROs working mainly in university hospitals and part-time in affiliated facilities was 44.5%. The corresponding data were 6.5% of ROs working primarily in cancer centers and 7.5% of ROs working mainly in other RT hospitals.

Patient loads

Figure 2(a) shows the patient load per RO working mainly in university hospitals, cancer centers, and other RT hospitals. Of ROs working primarily in university hospitals, 40.1% treated more than 200 patients per year. The corresponding ratios were 74.4% of ROs working primarily in cancer centers and 36.5% of those working mainly in other RT hospitals. The average number of patients treated by ROs working primarily in university hospitals was 189.2, with the corresponding figures being 256.6 patients in cancer centers and 176.6 in other RT hospitals. Figure 2(b) shows the patient load per RO working primarily in university hospitals. Of ROs working in university hospitals and affiliated facilities, 65.9% treated more than 200 patients per year, and the percentage was 19.3% of ROs working only in university hospitals. The former treated an average of 249.1 patients and the latter 144.0 patients per year.

The geographic patterns

Figure 3 shows the geographic distribution for 47 prefectures of the mean annual number of patients (new plus repeat) per RO arranged in order of increasing population by all prefectures in Japan (9). The average annual number of patients per RO per quarter ranged from 143.1 to 203.4, with significant differences among quarters ($p < 0.0001$). Figure 4 shows the top 10 prefectures with ROs who treated more than 200 patients per year in descending order: Tokyo, Osaka, Kanagawa, Hokkaido, Chiba, Aichi, Fukuoka, Hyogo, Miyagi, and Hiroshima.

Relative practice index for patients of ROs

Figure 5(a) shows the average relative practice index for patients of ROs in university hospitals and affiliated facilities (ROs working mainly in university hospitals). The average practice index of RO for patients was 1.07 at university hospitals and 0.71 at affiliated facilities for a statistically significant difference ($p < 0.0001$). Figure 5(b) shows the average relative practice index for patients of ROs working only in university hospitals, only in cancer centers, and only in other RT hospitals. The respective indices for the three categories were 1.26, 1.02, and 1.01. There were significant differences in the indices between university hospitals and cancer centers ($p = 0.0278$) and between university hospitals and other RT hospitals ($p < 0.0001$). The difference between cancer

Table 3. Overview of analyzed data

Main facility category	Number of full-time ROs working at main facilities	Number of part-time ROs working at affiliated facilities					
		First*	Second*	Third*	Fourth*	Fifth*	Subtotal
University hospital	372	160	59	14	4	2	239
Cancer center	78	5	0	0	0	0	5
Other radiotherapy hospital	504	34	2	0	0	0	36
Total	954	199	61	14	4	2	280

Abbreviation: RO = radiation oncologist.

* First: first affiliated facilities; second: second affiliated facilities; third: third affiliated facilities; fourth: fourth affiliated facilities; fifth: fifth affiliated facilities.

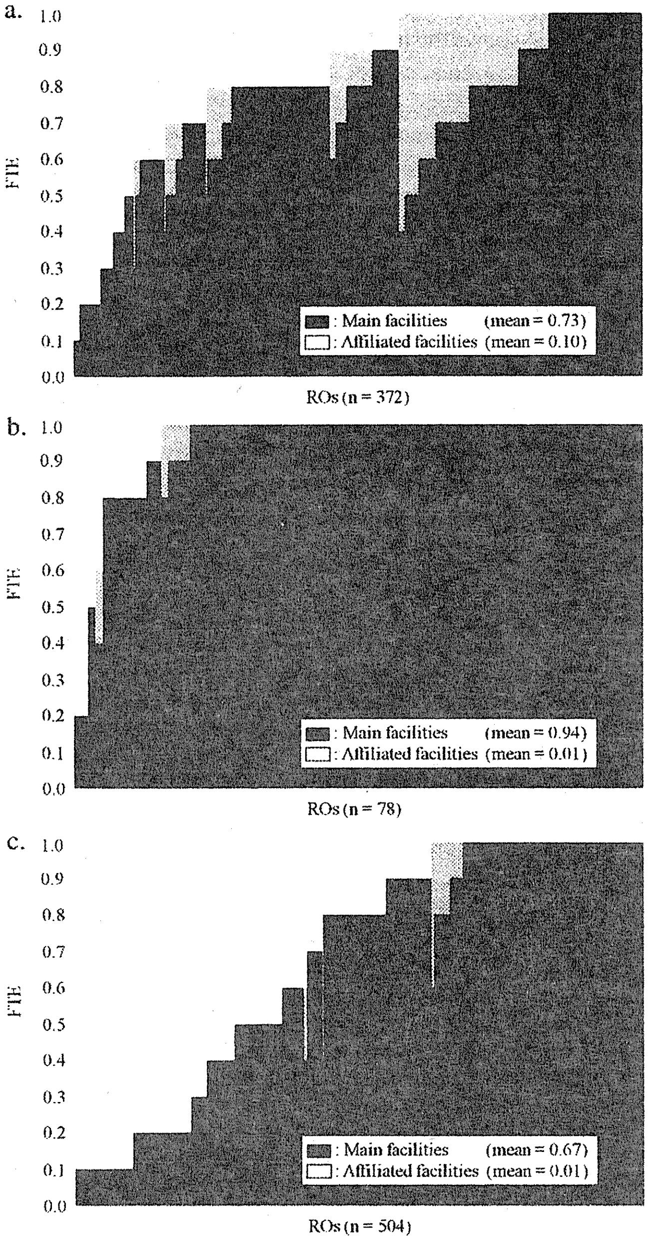

Fig. 1. Working patterns of ROs working mainly at (a) university hospitals, (b) cancer centers, and (c) other radiotherapy hospitals. Distribution of FTE ratio between main and affiliated facilities on each RO. Horizontal axis represents ROs in ascending order of own total FTE. *Abbreviations:* RO = radiation oncologist; FTE = full-time equivalent (40 hours per week for radiation oncology services only).

centers and other RT hospitals was not significant ($p = 0.9459$).

DISCUSSION

In the United States, most RT facilities are supported by full-time ROs, with an FTE of 1.0 for most ROs working at their own facilities. In Japan, on the other hand, more than a half of the facilities still rely on part-time ROs. The main reason of this discrepancy is a shortage of ROs. Between 2005 and 2007, the increase in the number of cancer patients requiring RT (7.3%) was higher than that in the number of FTE ROs (6.7%) (1). To make up for the shortage of ROs, most ROs in university hospitals must work part-time at affiliated hospitals, as is evident from the date shown in Figure 1. White parts of Figure 1 (a: 17.4%, b: 5.0% c: 32.0%) represent three types of data: (a) FTE data of ROs who were not provided in the survey questionnaire; (b) FTE data of part-time ROs whose identification data could not connect to those of full-time ROs; (c) FTE data of ROs working in nonradiation oncology services. In this survey, the data of type (a) and (b) were missing data and the data of type (c) were not collected. In other RT hospitals, the FTE of most ROs working in their own facilities is low and these ROs do not work part-time at other hospitals. There are two reasons for this. First, diagnosticians partly provide RT as ROs in their own hospitals and, second, other specialists (such as brain surgeons using gamma knife) partly function as ROs to provide RT. Because those facilities have few cancer patients, their patient load is less than that of university hospitals and cancer centers. These findings are evident from Figure 2(a). There was a major difference in the working patterns of ROs between university hospitals and cancer centers. FTE at their own facilities of most ROs working in university hospitals is less than 1.0, whereas that of most ROs working in cancer centers is 1.0,

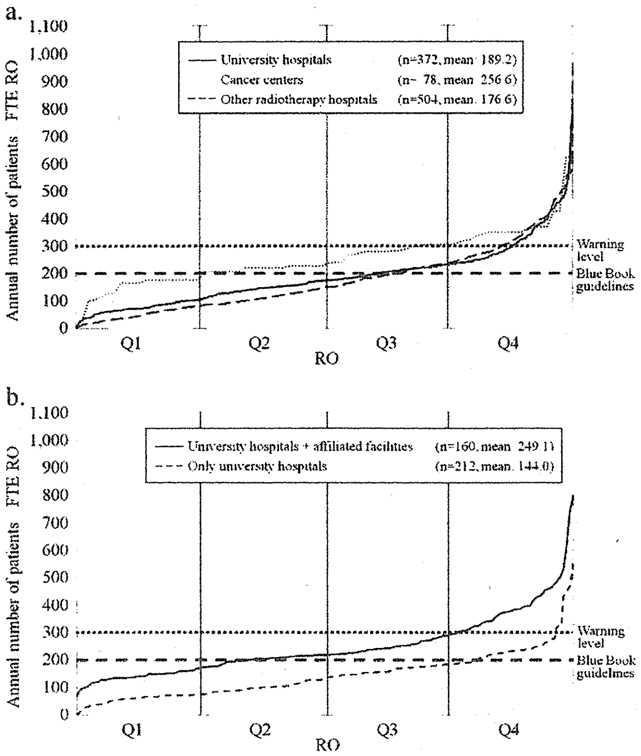

Fig. 2. Distribution of annual patient load/RO. (a) RO working mainly in university hospitals, cancer centers, and other radiotherapy hospitals. (b) RO working mainly in university hospitals. Horizontal axis represents ROs in ascending order of annual numbers of patients/RO. Q1: 0–25%, Q2: 26–50%, Q3: 51–75%, Q4: 76–100%. *Abbreviations:* RO = radiation oncologist; FTE = full-time equivalent (40 hours per week for radiation oncology services only).

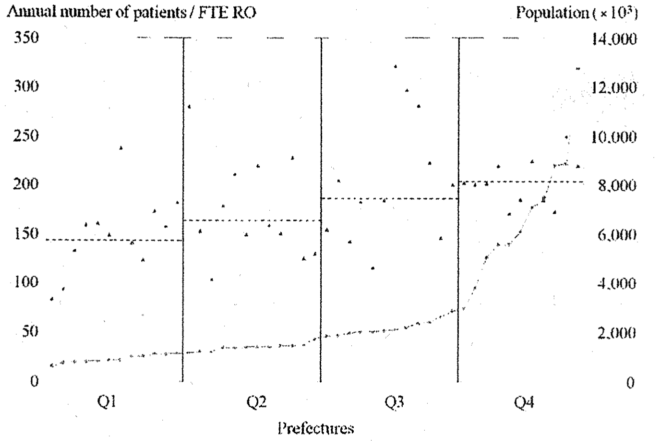

Fig. 3. Geographic distribution for 47 prefectures of annual number of patients (new plus repeat) per RO in ascending order of prefectural population. Q1: 0–25%; Q2: 26–50%; Q3: 51–75%; Q4: 76–100%. Triangles represent average annual number of patients per RO for each prefecture. Blue circles show prefectural population. Horizontal broken lines indicate the average annual number of patients per RO per quarter. The shaded area represents the Japanese Blue Book guideline (150–200 patients per RO). *Abbreviations:* RO = radiation oncologist; FTE = full-time equivalent (40 hours per week for radiation oncology services only).

the same as in the United States and European countries. The shortage of ROs is not the only reason for the problems facing Japan. The pay system of ROs is another important reason. The salary of ROs in Japan is low because specialist medical fees for ROs are not covered by the Japanese healthcare insurance system. Moreover, the salary of ROs in university hospitals is lower than in other types of facilities, so that most of these ROs must work part-time at affiliated hospitals to earn a living. One advantage of this system, however, is that advanced technology is introduced sooner and faster in affiliated hospitals.

The geographic patterns demonstrated significant differences in the patient load among prefectures, ranging from 83.2 to 321.4 patients per RO. There were more ROs in metropolitan than other areas. However, the number of ROs who had more than 200 patients (new plus repeat) was strongly associated with population (correlation coefficient: 0.94), so that the number of ROs in metropolitan area remained insufficient.

Gomi *et al.* reported that the survival rate of patients treated in academic RT facilities (university hospitals and cancer centers) was better than that of those treated in nonacademic RT facilities in Japan (10). In this study, the proportion of facilities with part-time ROs in nonacademic RT facilities group was higher than that in academic RT facilities group. Part-time ROs have less care time per patient because they had a limit to working hours. On the basis of the presented evidence, the relative practice index for patients of ROs was calculated as one way to valuate quality of cancer care in this study. Concerning ROs working primarily in university hospitals, the average relative practice index for patients in affiliated facilities was less than that in main facilities (university hospitals). Teshima *et al.* reported that academic RT facilities (university hospitals and cancer centers) had better equipments and manpower than nonacademic RT facilities (1). Therefore, ROs at large-scale university hospitals might be given sufficient support because large-scale university hospitals tend to have state-of-the-art equipment, practice leading-edge medical treatment techniques, and employ enough medical staff members. On the other hand, ROs of most affiliated facilities could provide only minimal cancer care because these facilities

Fig. 4. The top 10 prefectures with ROs who treated more than 200 patients in descending order: Tokyo, Osaka, Kanagawa, Hokkaido, Chiba, Aichi, Fukuoka, Hyogo, Miyagi, and Hiroshima. *Abbreviation:* RO = radiation oncologist.

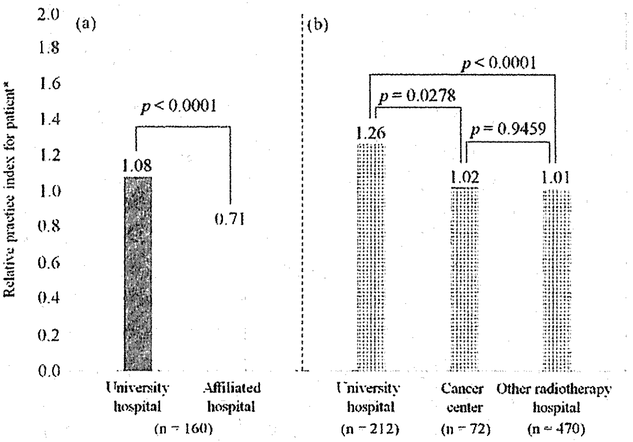

Fig. 5. Relative practice index for patients of ROs. (a) Relative practice index for patients in university hospitals and affiliated hospitals (targeted ROs were working mainly in university hospitals and part-time in affiliated hospitals). (b) Relative practice index for patients in university hospitals, cancer centers, and other radiotherapy hospitals (targeted ROs were working only in university hospitals or cancer centers only or only in other radiotherapy hospitals). *The formula used for calculating relative practice index for patients is: $\frac{\sum_{k=1}^{n} f_k}{\sum_{k=1}^{n} a_k} \times 200$ n: number of facilities that the RO works in (n = 1, 2, 3, …, k). f_k : FTE of the RO in facility k a_k : annual number of patients per RO in facility k. *Abbreviations:* RO = radiation oncologist; FTE = full-time equivalent (40 hours per week for radiation oncology services only).

tend to lack sufficient equipment and medical staff. Moreover, commuting between large-scale university hospitals and affiliated facilities resulted in a waste of time and in tiredness. Therefore, the quality of cancer care in affiliated facilities was worse than that in large-scale university hospitals. Although the annual number of patients per RO in cancer centers was higher than that in university hospitals and other RT hospitals, the average relative practice index for patients of ROs working only in cancer centers was lower than that for patients of ROs working only in university hospitals and equal to that for patients of ROs working only in other RT hospitals. It can thus be concluded that ROs in cancer centers worked efficiently.

The utilization rate of RT for new cancer patients in Japan is much lower than that in European countries and the United States. Because there are enough RT facilities distributed nationwide in Japan, an increase in the number of Ros would likely result in a spectacular improvement in the utilization rate of RT for new cancer patients. To increase the number of ROs, it is necessary to improve the work environment and conditions for radiation oncology in medical care facilities. One, feasible suggestion is for RT facilities to set up a new department of radiation oncology, so that the position of RO will be established at every such facility and the status of radiation oncology will improve as a result. In addition, the Cancer Control Act was approved in 2006 and the Basic Plan to Promote Cancer Control Program was approved by the Japanese Cabinet in 2007 to promote RT and education for ROs as well as other RT staff members. For the implementation of this law and plan, the availability of basic data of RO working conditions is essential. As a start, an education program called "Cancer Professional Training Plan" was started in April 2008 with the support of the Ministry of Education, Culture, Sports, Science and Technology.

Quality of cancer care was evaluated in this study with the aid of the relative practice index for patients. However, data concerning the processes and outcomes for cancer care using RT should be used for a more accurate evaluation of cancer care. In the United States, the National Cancer Data Base has been collecting data for cancer care. The data of National Cancer Data Base are useful for quality evaluation of cancer care (11, 12). Furthermore, PCS has been performed every 4 or 5 years since 1973 for a survey of the structure, processes, and outcomes of radiation oncology facilities (13). As PCS evolved into Quality Research in Radiation Oncology, periodic assessments of radiation oncology have been conducted for evaluation of practice quality on a national basis. In Japan, the structure, processes and outcomes for cancer care using RT have been investigated by PCS every 4 years (7, 8). The Japanese PCS has evaluated the quality of cancer care with RT and provided evidence of the disparity in quality of RT among facilities (14–18). However, these data are insufficient because PCS is a two-stage cluster sampling survey. We have recently established a database system based on available radiation oncology data and the collection of cancer care data by means of this system is now in preparation.

This study based on the JASTRO structure survey has indicated that the current national medical care system may impede fostering of true specialization of radiation oncologists in Japan because it is suffering from systemic fatigue. Although private hospitals make much money by receiving fee-for-service reimbursement, public hospitals face major deficit problems. It is therefore necessary to redistribute the burden of medical costs. On the other hand, the Japanese medical care system is beneficial for patients and national finances. Japan has had a universal health insurance system since 1961. Even though the per-capita medical costs in Japan were less than half of those in the United States and the medical costs in relation to the gross domestic product in Japan were about half of those in the United States as of 2007 (19), the outcome of cancer treatment in Japan is the same or better than in the United States. It is therefore very important to collect at regular intervals detailed information about all cancer care facilities for evaluation of quality of care and medical care systems for cancer. In Japan, the JASTRO structure survey has collected structural data of radiation oncology. Furthermore, a database system for the collection of data regarding the processes and outcomes for cancer care has recently been established in Japan as well as an information infrastructure for evaluation of the quality of care in radiation oncology.

In conclusion, our survey found that ROs working in university hospitals and their affiliated facilities treated more patients than did other ROs. In terms of patient care time only, the quality of cancer care in affiliated facilities might be worse than that in university hospitals. Under the current national insurance system, working patterns of ROs in academic facilities in Japan tend to impede the fostering of true specialization of radiation oncologists.

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Strahlentherapie
und Onkologie

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.

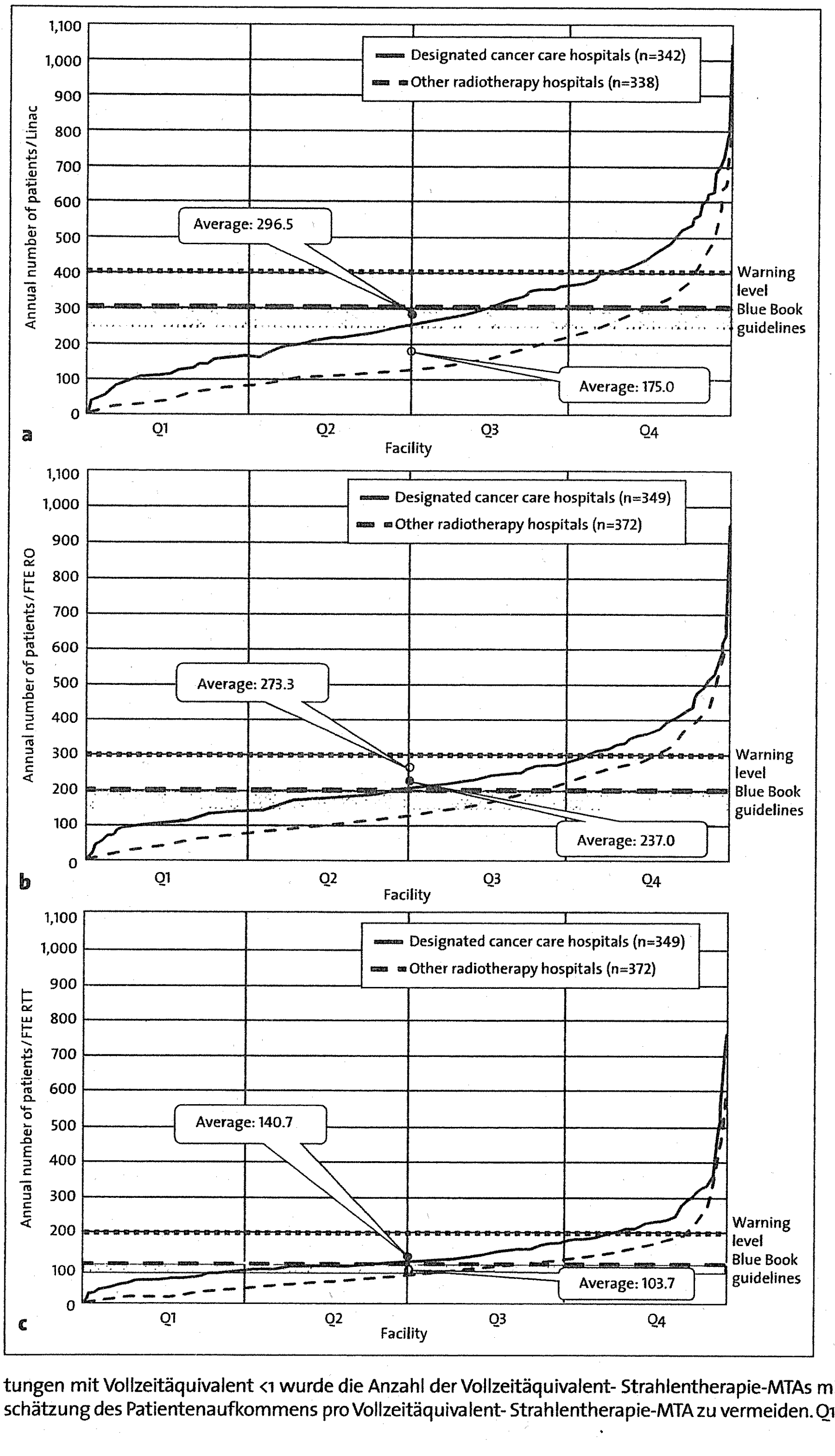
	Designated cancer care hospitals (n = 349)		Comparison with 2005	Others (n = 372)		Comparison with 2005	Total (n = 721)	
	n	%	%	n	%	%	n	%
Linac	453	98.0[a]	1.7[c]	354	90.9[a]	1.0[c]	807	94.3[a]
with dual energy function	339	74.8[b]	1.7[c]	200	56.5[b]	0.2[c]	539	66.8[b]
with 3D-CRT function (MLC width ≤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.

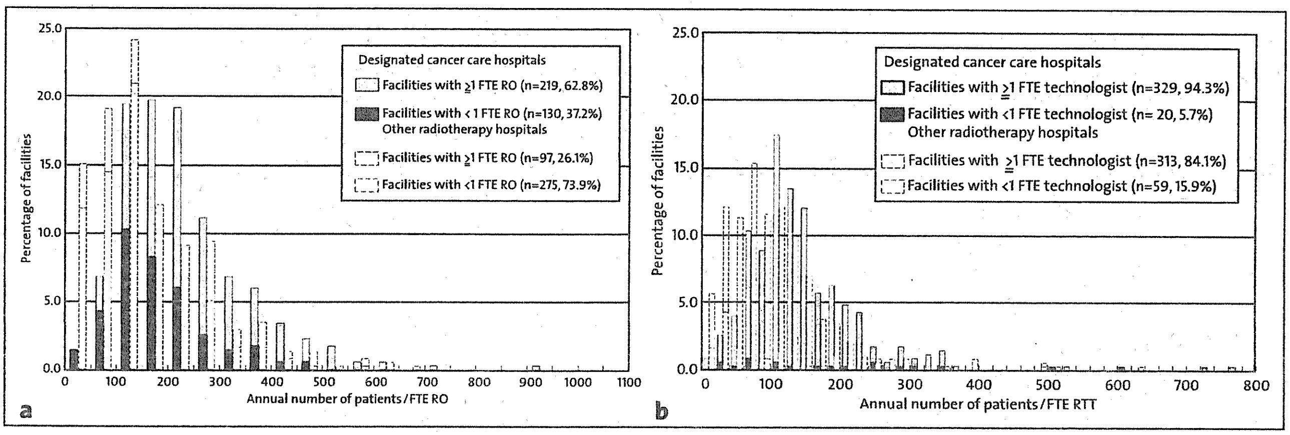
Geographic Patterns

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.

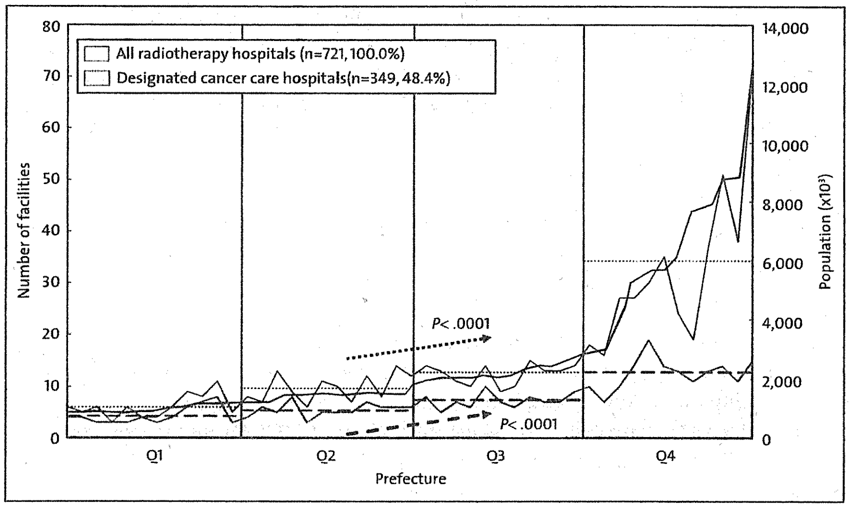


Figure 3. Geographic distribution for 47 prefectures of the number of facilities arranged in order of increase in population. The dotted line shows the average number of facilities of the prefectures per quarter for all radiotherapy hospitals and the dashed line shows the average number for designated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