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B. 乳房切除術後(進行乳癌)

学びのポイント

局所病と全身病の両者の性格を併せもつ乳癌に対し, 局所療法の一つである放射線治療を効果的に用いることは重要である。特に, 局所進行例や腋窩リンパ節転移陽性例では有効な全身療法を施行するとともに術後放射線治療を適切な時期に行うことで治療成績の向上が期待される。最近では三次元治療計画装置や位置照合システムなどを始めとする放射線治療技術の進歩に伴い, 安全かつ効果的な放射線治療が行えるようになった。進行期例では胸壁に加え領域リンパ節を照射範囲に含めることが勧められる。遅発毒性を減らすために可能な限り心臓や肺を照射野から外すよう細心の注意を払った放射線治療が重要である。

キーワード

原発乳癌, 初期治療, 術後補助療法, 放射線療法, 三次元治療計画, 局所再発, 乳房切除術後放射線治療

a. 意 義

かつての乳房切除術後の放射線治療は, 不適切な照射技術による心毒性の増加に加え, 適切な患者選択がなされなかったために生存率を向上させることができなかった。しかし, 1990年代後半に報告された3つの大きなランダム化比較試験により乳房切除後の放射線治療が局所再発率を低下させるだけでなく生存率をも向上させることが示された[1)~4)]。全身療法が進歩した現在でも放射線治療の有用性は変わらない[5)]。

b. 適 応

(1) 病理学的に4個以上の腋窩リンパ節転移が確認された症例においては乳房切除術後に胸壁および領域リンパ節を含めた術後照射を行うことが推奨されている[6)]。

(☞乳癌診療ガイドライン 放射線療法 CQ9-a)

(2) National Comprehensive Cancer Network (NCCN)においては腋窩リンパ節転移が1～3個の症例でも術後照射を行うことが強く勧められている。わが国の診療ガイドラインではリンパ節転移が1～3個の症例における術後照射は症例ごとに検討することとされている。現時点では論文化には至っていないが, 2011年の米国腫瘍学会(ASCO)において, リンパ節転移陽性例(1個以上転移あり)および高リスク症例を対象に領域リンパ節を照射野に含めることの臨床的意義を検証する共同試験MA.20の結果が報告され, 無再発生存期間の改善が報告された。本試験は乳房温存手術を施行した症例を対象とした試験結果ではあるが, 今後, 乳房切除術施行例においてもこの結果を外挿すべきかわが国でも検討を進める必要がある。

(☞ガイドライン 放射線療法 CQ9-b)

(3) 術前化学療法施行例においても術前の病期, および術後のリンパ節転移の状況などを考慮して術後照射を検討する。術前化学療法により病理学的腋窩リンパ節転移数が減少することが報告されており, 病理診断にてリンパ節転移が1～3個であった場合には判断に迷うことがある。

(☞ガイドライン 放射線療法 CQ11)

(4) 放射線治療の相対的禁忌としては，背臥位にて患側上肢が挙上不能な患者や活動性の高い膠原病患者(強皮症やSLE)，遺伝性疾患である色素性乾皮症を有する患者などである。後二者は放射線治療後の重篤な有害事象が生じることが報告されている。患側上肢挙上が不十分な症例では照射時と同じ姿勢で撮影する治療計画CTが施行できず放射線治療計画が施行できないことがある。また，CT撮影は行えたとしても，照射開始後に鎖骨上窩と胸壁の照射野の接合部にずれが生じるなどの問題が起き得るため，放射線治療を計画する時点で無理なく上肢が挙上できることが重要である。 (☞ガイドライン 放射線療法 CQ8-b)

c. 放射線治療技術

1) 胸壁照射

適正な照射部位と照射線量が治療成績向上の鍵を握ることが報告されている[7]。乳房切除後の放射線治療においては，患側胸壁と鎖骨上窩を照射野に含めることが一般的である。鎖骨上窩は前方からの照射で，胸壁は接線照射で放射線治療を行うが，両部位の照射野の接合部に重なりが生じないよう細心の注意が必要である(図1)。50 Gy/25分割/5週間の照射スケジュールが用いられることが多く，切除断端陽性例では10 Gy/5分割/1週間程度の追加照射が行われる。乳房温存療法の際の乳房への照射と異なり，乳房全体が切除されており胸壁は薄く皮下直下から残された胸筋までをターゲットとすることとなる。ボーラス材を用いて表面線量を上げる工夫が必要となる。

胸壁の接線照射では可能な限り肺や心臓を避け，胸壁内の線量分布の均等性を保つことが重要である。また，均等性を改善するための方法として楔フィルタの使用やfield-in-field法を用いることがある。近年では，進行期癌に対してはアンスラサイクリン系薬剤や分子標的治療薬など心毒性がある薬剤が投与される機会が増え，左側胸壁を照射する際には心臓への線量を軽減させる工夫が必要である。現在の三次元治療計画では心臓への線量を下げる工夫が比較的容易に行えるが，胸郭の形によっては心臓が胸郭前面に張り出すような症例では三次元治療計画を用いても十分に心臓を照射範囲から外すことができない場合がある。この問題を解決する方法として呼吸同期照射法を用いて吸気時に肺が拡張し心臓が背側に移動したタイミングで照射する方法が開発されている。しかし，特殊な装置が必要なこと，安定した呼吸リズムを行えること，吸気相の一部のタイミングだけで照射を行うため照射に時間がかかるなどの欠点があり，この方法を実践している施設はわが国では限られる。切除断端陽性または近接例に対しては追加照射(ブースト照射)が行われる。追加照射のスケジュールは電子線を用いて10 Gy/5分割/1週間のスケジュールが用いられている。手術時に腫瘍床にクリップを留置しておくと追加照射の適切な範囲と適切な電子線のエネルギーの選択に役立つ。 (☞ガイドライン 放射線療法 CQ10-a)

2) 鎖骨上窩への照射

胸壁照射の上縁との重なりを避ける方法にはいくつかの方法があるが，現在ではhalf-field techniqueを用いるのが一般的である(図1)。1回線量は1.8〜2.0 Gyで50〜50.4 Gy程度が投与される。乳房切除術が施行された場合には腋窩のレベルIとIIが郭清されているため，放射線治療で鎖骨上窩を照射する場合には，胸鎖乳突筋の内側縁〜腋窩レベルIII(小胸筋内側)を中心に照射野を作成する。三次元治療計画を行う際にはRTOG(Radiation Therapy Oncology Group)のBreast Cancer Contouring Atlasを参考にすると良い[8]。傍胸骨リンパ節への照射を一律に施行すべきかに関する統一見解はないが，乳房切除術後の放射線治療が生存率の向上を証明したランダム化比較試験では傍胸骨リンパ節領域への照射を採用している[1)〜3)]。しかし，傍胸骨リンパ節領域への照射は肺や心臓への線量が増える可能性があり，注意深い照射野作成が必要である。

(☞ガイドライン 放射線療法 CQ10-b)

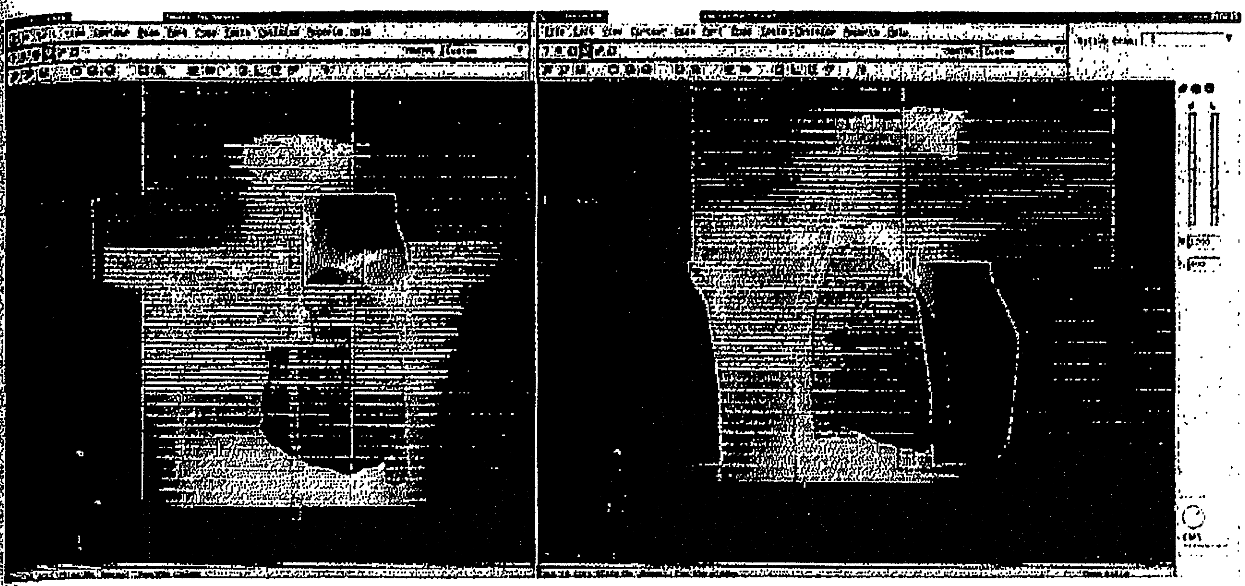

図 1. 乳房および鎖骨上窩への照射

d. 放射線治療のタイミング

(1) 術後化学療法を施行する症例においては化学療法を先行させ，終了後に放射線治療を行うのが一般的である。至適順序に関する十分な情報はないが，MDアンダーソンがんセンターからの後ろ向き研究では化学療法を先行させ放射線治療を遅らせても局所領域再発率は増加しないことが報告されており，遠隔転移の危険性の高い局所進行乳癌では化学療法を先行させることが多い[9]。

一部の抗癌薬では放射線治療との同時併用の安全性が報告されているが，アンスラサイクリン系を含む化学療法と放射線治療の併用は心毒性が増すことが報告されている[10]。また同時併用の上乗せ効果も証明されておらず，化学療法と放射線療法を同時併用すべきではない。化学療法を放射線治療と同時併用することは推奨されないが，内分泌療法と放射線療法の同時併用は一般臨床でもよく行われており，大きな毒性を生じることは少ない。　(☞ガイドライン 放射線療法 CQ12)

(2) 分子標的治療薬との同時併用に関する十分な情報はないが，短期的な経過観察の報告では重篤な毒性は報告されていない。しかし，長期経過観察はなされておらず，特にトラスツズマブ投与例では左側胸壁を照射する際には心臓を照射野から可能な限り外すよう三次元治療計画装置を用いて治療計画を立案する必要がある。

(☞ガイドライン 放射線療法 CQ5-e)

(3) 乳房再建と術後照射のタイミングに関して統一見解は得られていないが，術後照射が予定されている場合には一期的再建を避け，化学療法や放射線治療が終了した後に再建術を行うことが勧められている[6]。特に，インプラントを用いた再建術後の放射線治療では，被膜萎縮やインプラントの逸脱などが報告されており，現時点ではインプラントによる再建術後の放射線治療は推奨されない。　(☞ガイドライン 放射線療法 CQ13)

e. 有害事象

1) 急性毒性

胸壁照射の有害事象としては，軽度の皮膚炎がほぼ全例に認められる。表面線量を上げるために用いるボーラス材の影響で一部の症例では腋窩部や胸壁の一部にgrade 2～3の皮膚炎が生じることがある(図 2)。流水により滲出液と壊死物質の除去を行い，その後，保湿用の軟膏を塗布すると約1週間程度で皮膚炎は改善する。また，軽微ではあるが照射期間中に全身倦怠感を生じることがあるが，照射の休止を要することは稀である。鎖骨上窩への照射により生じる有害事象としては，

図2. 放射線皮膚炎

grade 1～2の皮膚炎と咽頭炎が認められる。

2）遅発毒性

一部の症例では遅発毒性として肺臓炎，肋骨骨折，上肢の浮腫などがみられる。稀に腕神経叢麻痺を生じることがあるが，鎖骨上窩への照射の際に1回線量を2Gy以下にすることでその発生頻度を抑えることができる。このほか，放射線治療による遅発性有害事象として対側乳癌，白血病，二次発癌などが挙げられるが，放射線治療の有用性のほうが大きく上回ると考えられている。

(☞ガイドライン 放射線療法 CQ14)

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朝日出版社

Int J Clin Oncol
DOI 10.1007/s10147-012-0468-7

ORIGINAL ARTICLE

Japanese structure survey of radiation oncology in 2009 with special reference to designated cancer care hospitals

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Received: 30 March 2012 / Accepted: 5 August 2012

Abstract

Background The structure of radiation oncology in designated cancer care hospitals in Japan was surveyed in terms of equipment, personnel, patient load, and geographic distribution, and compared with the structure in other radiotherapy facilities and the previous survey.

Methods The Japanese Society for Therapeutic Radiology and Oncology surveyed the national structure of radiation oncology in 2009. The structures of 365 designated cancer care hospitals and 335 other radiotherapy facilities were compared.

Results Designated cancer care hospitals accounted for 50.0 % of all the radiotherapy facilities in Japan. The patterns of equipment and personnel in designated cancer

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Published online: 28 September 2012

care hospitals and the other radiotherapy facilities were, respectively, as follows: linear accelerators per facility: 1.4 and 1.0; dual-energy function: 78.6 and 61.3 %; three-dimensional conformal radiotherapy function: 88.5 and 70.0 %; intensity-modulated radiotherapy function: 51.6 and 25.3 %; annual number of patients per linear accelerator: 301.3 and 185.2; Ir-192 remote-controlled afterloading systems: 31.8 and 4.2 %; and average number of full-time equivalent radiation oncologists per facility: 1.8 and 0.8. Compared with the previous survey, the ownership ratio of equipment and personnel improved in both designated cancer care hospitals and the other radiotherapy facilities. Annual patient loads per full-time equivalent radiation oncologist in the designated cancer care hospitals and the other radiotherapy facilities were 225.5 and 247.6, respectively. These values exceeded the standard guidelines level of 200.

Conclusions The structure of radiation oncology in designated Japanese cancer care hospitals was more mature than that in the other radiotherapy facilities. There is still a shortage of personnel. The serious understaffing problem in radiation oncology should be corrected in the future.

Keywords Radiotherapy · Medical engineering · Epidemiology

Introduction

In Japan, the current utilization rate of radiotherapy (RT) for new cancer patients in Japan is only 27.7 % and surgery remains predominant [1]. This rate is very low when compared to those for western developed countries. The main reason for this is that there is not enough personnel, such as radiation oncologists (ROs), medical physicists (MPs), and radiotherapy technologists (RTTs) [2, 3]. The Cancer Control Act was implemented in 2007 in response to patients' urgent petitions to the Japanese government [4]. This law strongly advocates the promotion of RT and an increase in the number of ROs and MPs. At the same time, the Ministry of Health, Labour 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 among regional cancer care hospitals [5, 6]. The Japanese Society for Therapeutic Radiology and Oncology (JASTRO) has conducted national structure surveys of RT facilities in Japan every 2 years since 1990 [7]. Findings of these surveys indicate that the structure of radiation oncology in Japan has improved in terms of equipment and functioning in response to the increasing numbers of cancer patients who require RT.

In the study presented here, the structure of radiation oncology in DCCHs in Japan was analyzed in terms of equipment, personnel, patient load, and geographic distribution, and compared with these features in other RT facilities in Japan. In addition, the recent structure of RT facilities was compared with that surveyed in 2007 [2] and the medical care situation in Japan was compared with that in European countries and the USA.

Methods and materials

A national survey in the form of a questionnaire on the structure of radiation oncology in Japan in 2009 was conducted by JASTRO from March 2010 to January 2011 [1]. The questionnaire consisted of items related to the number of treatment machines and type of modality, the number of personnel by job category, and the number of patients by type and disease site. The response rate was 90.9 % (700 out of 770) from all actual RT facilities in Japan. The number of DCCHs certified by the Ministry of Health, Labor and Welfare was 375 as of April 1, 2011 [8]. Of this total, 51 were designated prefectural and 324 were designated regional cancer care hospitals. The surveys were not returned by 20 facilities, and 3 facilities did not have departments of RT at the time of the survey, so that the structures of 365 DCCHs and 335 other RT facilities were analyzed. In this survey, full-time equivalent (FTE) (40 h/week for radiation oncology work only) data were surveyed in terms of the clinical working hours for RT of each staff member. SAS® 8.02 (SAS Institute Inc., Cary, NC, USA) [9] was used for the statistical analysis and statistical significance was determined by means of the χ^2 test and Student's t test.

The Japanese Blue Book Guidelines (JBBG) [10, 11] 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) [12, 13] data. The standard guidelines for annual patient load per external beam equipment were set at 250–300 (warning level 400), those for annual patient load per FTE RO at 200 (warning level 300), and those for annual patient load per FTE RT technologists at 120 (warning level 200).

Results

Current situation of radiation oncology

Table 1 shows the current situation of radiation oncology in Japan. DCCHs accounted for 50.0 % (385/770) of all the RT facilities in Japan. The numbers of new patients and total patients in all RT facilities in Japan were estimated at approximately 201,000 (182,390 × 770/700) and 240,000 (205,087 × 770/700), respectively. For DCCHs,

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

	DCCHs	Other RT facilities	*p* value (95 % CI)[a]	Total
Facilities	365	335	–	700
New patients	126,123[b]	56,267	–	182,390[c]
Average new patients/facility	345.5	168.0	<0.0001 (146.7, 208.4)	260.6
Total patients (new + repeat)	150,215[b]	67,614	–	217,829[c]
Average total patients per facility	411.5	201.8	<0.0001 (171.6, 247.8)	311.2

DCCH designated cancer care hospital, *RT* radiotherapy, *CI* confidence interval

[a] Student's *t* test

[b] The number of designated cancer care hospitals with RT was 385, and the number of new patients in DCCHs was estimated at approximately 134,000; the corresponding number of total patients (new plus repeat) was 159,000

[c] The number of radiotherapy facilities was 770 in 2009, and the number of new patients was estimated at approximately 201,000; the corresponding number of total patients (new plus repeat) was 240,000

the corresponding numbers were approximately 134,000 (126,123 × 385/365) and 159,000 (150,215 × 385/365). The number of new patients and total patients in DCCHs thus accounted for approximately 66.7 % (134,000/201,000) and 66.3 % (134,000/201,000 and 159,000/240,000) of the number of new patients and total patients in all RT facilities. The average numbers of new patients per facility were 345.5 for DCCHs and 168.0 for the other RT facilities, and for the average numbers of total patients per facility the corresponding figures were 411.5 and 201.8, respectively.

Facility and equipment patterns and patient load per linear accelerator

The RT equipment patterns and related functions in Japan are shown in Table 2. In DCCHs, 496 linear accelerators (linacs) and 116 ^{192}Ir remote-controlled after-loading systems (RALSs) were in current use, while the corresponding data for the other RT facilities were 320 and 14, respectively. The rate of equipment ownership at DCCHs was significantly higher than at the other RT facilities. As for the linac systems in DCCHs, the dual-energy function was used in 390 (78.6 %), the three-dimensional conformal radiotherapy (3D-CRT) function in 439 (88.5 %), and the IMRT function in 256 (51.6 %). For the other RT facilities, the corresponding figures were 196 (61.3 %), 224 (70.0 %), and 81 (25.3 %). The patient load per linac was 301.3 at DCCHs and 185.2 at the other RT facilities. Compared with the data for DCCHs in 2007 [2], the rate of linac ownership increased by 0.6 % while the rates of increase for installation of the various functions used with linacs were 3.8 % for dual-energy, 13.2 % for 3D-CRT, and 15.2 % for IMRT function. At the other RT facilities, the rate of linac ownership decreased by 0.4 %, while the rates of installation corresponding to those for DCCHs increased by 4.8, 9.5, and 5.5 %. The patterns for radiotherapy planning systems (RTPs) and other equipment are shown in Table 2. X-ray simulators were installed in 56.7 %, computed tomography (CT) simulators in 83.3 %, and RTPs in 97.3 % of the DCCHs, while the corresponding percentages for the other RT facilities were 44.2, 70.4, and 94.6 %. 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 2007 [3], X-ray simulator ownership at DCCHs decreased by 12.6 %, while CT simulator and RTP ownership increased by 8.2 and 0.5 %, respectively. At the other RT facilities, X-ray simulator ownership decreased by 8.8 % while CT simulator and RTP ownership increased by 13.7 and 0.8 %, respectively.

The distribution of annual patient load per linac in Japan is shown in Fig. 1. The patient load at 19.4 % of DCCHs and 4.6 % of the other RT hospitals exceeded the JBBG warning level of 400 patients per linac, but the average patient load per linac at the other facilities was below that level. Compared with the data for 2007 [2], the rate of facilities exceeding the JBBG warning level (400 patients per linac) decreased at both DCCHs (−0.8 %) and the other RT facilities (−0.7 %). However, the average number of total patients per facility increased at both DCCHs (1.6 %) and the other RT facilities (5.9 %).

Staffing patterns and patient loads

Staffing patterns and patient loads in Japan are detailed in Table 3. The figures for total FTE ROs were 666.3 for DCCHs and 273.1 for the other RT facilities, while the corresponding average numbers of FTE ROs per facility were 1.8 and 0.8 and for patient load per FTE RO 225.5 and 247.6. The distribution of annual patient load per FTE RO in Japan is illustrated in Fig. 2. More than 300 patients per RO (JBBG warning level) were treated in 23.3 % of DCCHs and in 10.7 % of the other facilities. Figure 3 shows the distribution of facilities by patient load per FTE RO, with the largest number featuring a patient per FTE RO level in the 100–149 range for DCCHs and the other

Table 2 Items of equipment, their function and patient load per unit of equipment in designated cancer care hospitals and other radiotherapy hospitals

	DCCHs (n = 365)		Comparison with 2007	Other RT facilities (n = 335)		Comparison with 2007	p value (95 % CI)	Total (n = 700)	
	n	%	%	n	%	%		n	%
Linac	496	98.6[a]	0.6[c]	320	90.4[a]	−0.4[c]	<0.0001[f]	816	94.7[a]
With dual energy function	390	78.6[b]	3.8[c]	196	61.3[b]	4.8[c]	<0.0001[f]	586	71.8[b]
With 3D-CRT function (MLC width ≤1.0 cm)	439	88.5[b]	13.2[c]	224	70.0[b]	9.5[c]	<0.0001[f]	663	81.3[b]
With IMRT function	256	51.6[b]	15.2[c]	81	25.3[b]	5.5[c]	<0.0001[f]	337	41.3[b]
Average no. linac per facility	1.4	–	4.7[e]	1.0	–	0.4[e]	<0.0001 (0.3, 0.4)[g]	1.2	–
Annual no. patients per linac	301.3[d]	–	1.6[e]	185.2[d]	–	5.9[e]	<0.0001 (86.8, 133.9)[g]	255.8[d]	–
^{192}Ir RALS (actual use)	116	31.8[a]	2.3[c]	14	4.2[a]	−1.2[c]	<0.0001[f]	130	18.6[a]
X-ray simulator	211	56.7[a]	−12.6[c]	150	44.2[a]	−8.8[c]	0.0009[f]	361	50.7[a]
CT simulator	324	83.3[a]	8.2[c]	251	70.4[a]	13.7[c]	<0.0001[f]	575	77.1[a]
RTP computer	854	97.3[a]	0.4[c]	417	94.6[a]	0.8[c]	0.0757[f]	1,271	96.0[a]

DCCH designated cancer care hospital, *RT* radiotherapy, *CI* confidence interval, *Linac* linear accelerator, *IMRT* intensity-modulated radiotherapy, *RALS* remote-controlled after-loading system, *CT* computed tomography, *3D-CRT* three-dimensional conformal radiotherapy, *RTP* radiotherapy planning

[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 2007, calculated using the formula: data of 2009 (%) – data of 2007 (%)

[d] Percentage calculated from the number of patients and the number of linac units. Facilities without linacs were excluded from the calculation

[e] Rate of increase compared with the data of 2007, calculated using the formula: $\frac{\text{data of 2009 }(n) - \text{data of 2007 }(n)}{\text{data of 2007 }(n)} \times 100\ (\%)$

[f] χ^2 test

[g] Student's t test

RT facilities. Facilities with less than 1 FTE RO still account for about 31.2 % of DCCHs and 65.7 % of the other RT facilities. The average numbers of FTE ROs per facility and full-time JASTRO-certified ROs per facility at DCCHs increased by 11.5 and 6.7 %, respectively, compared with 2007 data, and for the other RT facilities, those numbers increased by 18.9 and 22.3 %. The annual patient load per FTE RO, on the other hand, decreased by 4.9 % at DCCHs and 9.4 % at the other RT facilities.

The total numbers of FTE RTTs were 1175.7 for DCCHs and 660.2 for the other RT facilities, and the corresponding average numbers of RTTs per facility were 3.2 and 2.0, while the patient loads per FTE RTT were 127.8 and 102.4. The distribution of annual patient load per FTE RTT in Japan is shown in Fig. 4. More than 200 patients per RTT (JBBG warning level) were treated in 11.0 % of DCCHs and in 7.5 % of the other RT facilities, while Fig. 5 shows the distribution of facilities by patient load per FTE RTT. The largest number of facilities featured a patient per FTE RTT level in the 100–119 range for DCCHs and the other RT facilities. The total numbers of FTE MPs and FTE RT nurses were 74.6 and 392.8, respectively, for DCCHs and 43.0 and 228.4 for the other RT facilities.

Distribution of primary disease sites and palliative treatment

Table 4 shows the distribution of primary disease sites and palliative treatment at DCCHs and the other RT facilities. The most common disease site at DCCHs and the other RT facilities was the breast. Head/neck, esophagus, liver/biliary tract/pancreas, gynecologic, urogenital, prostate, hematopoietic/lymphatic, and skin/bone/soft tissue cancers were treated at higher rates at DCCHs than at the other RT facilities. The rates for other cancers were the reverse. Compared with the data for 2007, the percentage of breast cancers increased the most at DCCHs (1.4 %), and at the other RT facilities the percentage of head/neck and breast cancers increased significantly (2.4 and 2.3 %).

Brain metastasis was treated at higher rates at the other RT facilities (14.7 % of total patients) than at DCCHs (6.9 % of total patients), while the reverse was true for

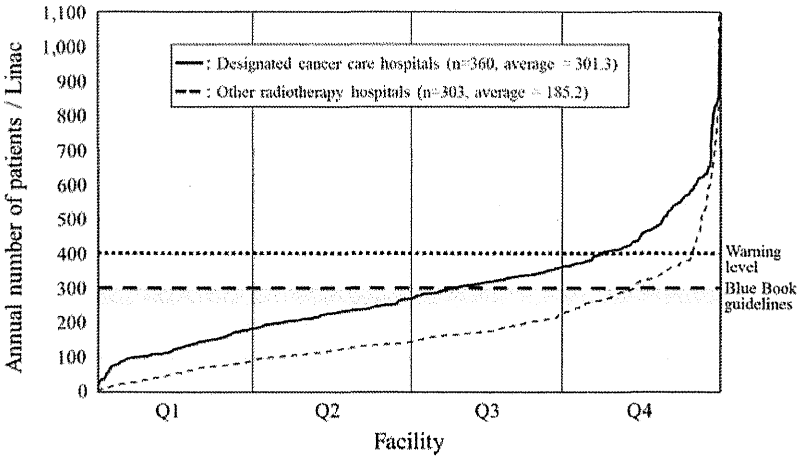


Fig. 1 Distribution of annual patient loads per linear accelerator in designated cancer care hospitals and the other radiotherapy facilities. *Horizontal axis* represents facilities arranged in order of increasing value of annual number of patients per treated equipment within facilities. *Q1* 0–25 %, *Q2* 26–50 %, *Q3* 51–75 %, *Q4* 76–100 %

Table 3 Structure and personnel of designated cancer care hospitals and other radiotherapy hospitals

	DCCHs ($n = 365$)	Comparison with 2007[a] (%)	Other RT facilities ($n = 335$)	Comparison with 2007[a] (%)	p value[b]	Total ($n = 700$)
Facilities with RT beds	190	–	108	–	–	298 (42.6)
Average no. RT beds per facility	4.2	−1.5	2.2	11.5	–	3.3
Total (full + part-time) RO FTE	666.3	–	273.1	–	–	939.4
Average no. FTE ROs per facility	1.8	11.5	0.8	18.9	<0.0001	1.3
JASTRO-certified RO (full-time)	422	–	109	–	–	531
Average no. JASTRO-certified ROs per facility	1.2	6.7	0.3	22.3	<0.0001	0.8
Annual no. patients per FTE RO	225.5	−4.9	247.6	−9.4	<0.0001	231.9
Total (full + part-time) RT technologist FTE	1175.7	–	660.2	–	–	1836.0
Average no. FTE RT technologists per facility	3.2	16.8	2.0	9.1	<0.0001	2.6
Annual no. patients per FTE RT technologist	127.8	−9.2	102.4	−1.3	<0.0001	118.7
Total (full + part-time) medical physicist FTE	74.6	77.7	43.0	62.9	–	117.6
Total (full + part-time) RT nurse FTE	392.8	29.1	228.4	20.1	–	621.2

DCCH designated cancer care hospital, *RT* radiotherapy, *RO* radiation oncologist, *FTE* full-time equivalent (40 h/week only for RT practise), *JASTRO* Japanese Society for Therapeutic Radiology and Oncology

[a] Rate of increase compared with the data of 2007, calculated using the formula: $\frac{\text{data of 2009 } (n) - \text{data of 2007 } (n)}{\text{data of 2007 } (n)} \times 100\ (\%)$

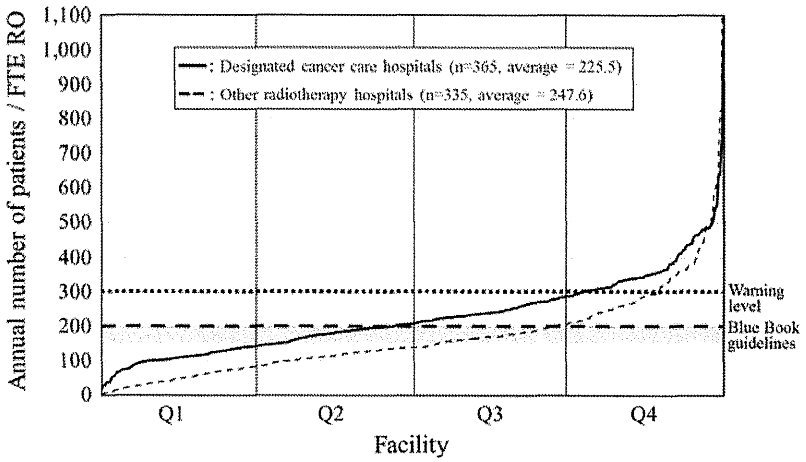
[b] Student's t test

bone metastasis (11.3 and 12.8 %, respectively). Compared with the data for 2007, the rate of brain and bone metastasis decreased in both DCCHs (−0.7 and −0.9 %) and the other RT facilities (−1.0 and −2.3 %).

Discussion

The utilization rate of RT for new cancer patients in Japan is less than half of that in developed countries in Europe and in the USA [14]. However, RT is expected to play an increasingly important role in Japan because the increase in the elderly population is the highest among developed countries. The distribution of facilities by patient load per RO for DCCHs proved to be largely similar to that of the USA in 1989 [15]. While the numbers of ROs in both DCCHs and the other RT hospitals in Japan has increased, the facilities which have less than one FTE RO still account for 31.2 % of DCCHs and 65.7 % of the other RT facilities. In Japan, the majority of facilities still rely on

Fig. 2 Distribution of annual patient loads per FTE RO in designated cancer care hospitals and the other radiotherapy facilities. *Horizontal axis* represents facilities arranged in order of increasing value of annual number of patients per FTE RO within facilities. *Q1* 0–25 %, *Q2* 26–50 %, *Q3* 51–75 %, *Q4* 76–100 %. Number of FTE RO for facilities with FTE <1 was calculated as FTE = 1 to avoid overestimating patient loads per FTE RO



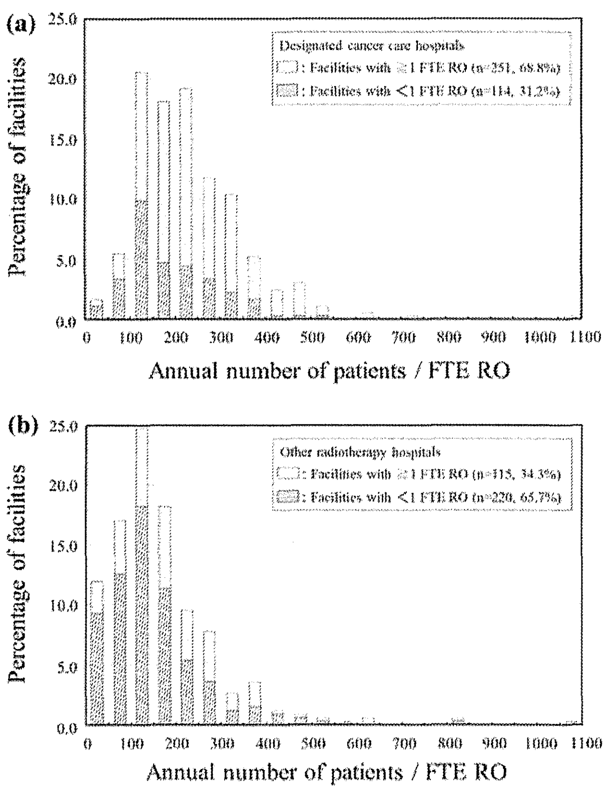


Fig. 3 Percentage of facilities by patient loads per FTE RO in designated cancer care hospitals (**a**) and in the other radiotherapy hospitals (**b**). *Each bar* represents an interval of 50 patients per FTE RO. Number of FTE RO for facilities with FTE <1 was calculated as FTE = 1 to avoid overestimating patient loads per FTE RO

part-time ROs, especially in facilities other than DCCHs, but in western developed countries, most facilities have at least 1 full-time RO. The distribution in Japan of facilities by patient load per RO for the other RT facilities in this study was similar to that in 1990 [15], so that a shortage of ROs has remained a major concern. More than 300 patients per RO (JBBG warning level) were treated in 17.6 % of all RT facilities. This is a matter of critical importance to the quality of radiotherapy.

A new educational system called "Cancer Professional Training Plan" by the Ministry of Education, Culture, Sports, Science and Technology, Japan is being developed in Japan to train specialists for cancer care, including ROs, MPs, medical oncologists, oncology nurses, and palliative care doctors. The average number of RT staff members at DCCHs was greater than that in the other RT hospitals. As noted above, there is still a shortage of Ros, although the numbers have increased. In Japan, many RT hospitals do not have an independent department for RT. One way to increase the number of ROs is to create an independent department for RT. The numbers of MPs in Japan are still smaller than those in western developed countries, and they work mainly in metropolitan areas or academic facilities, such as university hospitals or cancer centers. At present, no national license is available 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). Compared with ROs and MPs, a sufficient number of RTTs is ensured in Japan. However, there is a significant number of hospitals with less than 1 FTE RTT in both DCCHs ($n = 13$) and the other RT hospitals ($n = 50$). In addition, many RTTs are extremely busy because they must also partially act as MPs. As for equipment, the ownership of equipment for advanced high-precision radiation therapy machines increased compared with 2007 at all RT facilities, especially DCCHs, indicating that the accreditation of DCCHs closely correlates 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 towards a more balanced geographic consolidation of RT facilities in Japan.

The findings of this study show that, on a regional basis, DCCHs were located in the most suitable areas. There were

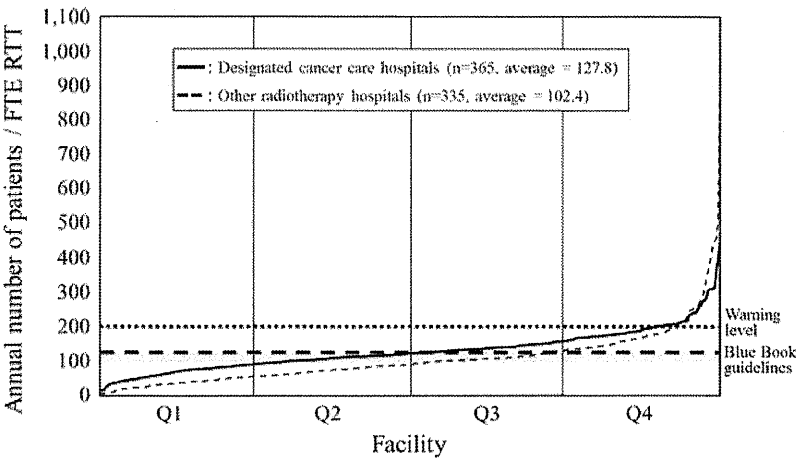


Fig. 4 Distribution of annual patient loads per FTE RTT in designated cancer care hospitals and the other radiotherapy facilities. *Horizontal axis* represents facilities arranged in order of increasing value of annual number of patients per FTE RTT within facilities. *Q1* 0–25 %, *Q2* 26–50 %, *Q3* 51–75 %, *Q4* 76–100 %. Number of FTE RTT for facilities with FTE <1 was calculated as FTE = 1 to avoid overestimating patient loads per FTE RTT

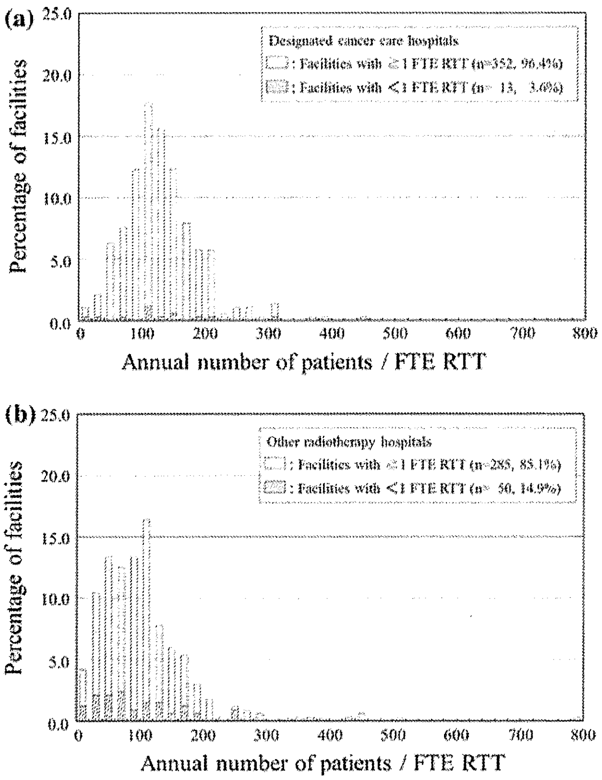


Fig. 5 Percentage of facilities by patient loads per FTE RTT in designated cancer care hospitals (**a**) and in the other radiotherapy hospitals (**b**). *Each bar* represents an interval of 20 patients per FTE RTT. Number of FTE RTT for facilities with FTE <1 was calculated as FTE = 1 to avoid overestimating patient loads per FTE RTT

388 DCCH facilities by the end of fiscal year 2011 because some further university facilities with many patients undergoing RT had been certified as DCCHs since the previous survey, while some small-scale facilities were not certified as DCCHs by the Ministry of Health, Labor, and Welfare. In terms of nationwide distribution, there seem to be enough RT facilities in Japan. On the other hand, the RT potential of RT facilities other than DCCHs in Japan remains unrealized because of personnel shortages. The most frequent primary disease site treated with RT at the other RT facilities changed from lung/trachea/mediastinum to breast, compared with the data for 2007, while at DCCHs, the most frequently treated primary disease site, the breast, remained unchanged from 2007. Finally, the number of patients with brain and bone metastasis did not increase since 2007.

To evaluate medical care systems for cancer at regular intervals, it is very important to collect detailed information on all cancer care facilities. In Japan, the structural data for all RT facilities is regularly surveyed by JASTRO. In addition, the procedures and the outcome data of cancer care for patients undergoing RT have been conducted by PCS every 4 years, but insufficient outcome data is collected. In the USA, a National Cancer Data Base was established in 1989 and since then has been collecting comprehensive data on cancer care, and this database is used as the quality indicator for improvements in the processes and outcomes of cancer care [16, 17]. We have established a Japanese National Cancer Database based on the RT data in Japan and we are preparing to use this system for the collection of cancer care data.

In conclusion, the RT structure of DCCHs in Japan showed more maturity than that of other RT facilities in terms of equipment, functions, and staff. However, there is still a shortage of personnel (ROs, RTTs, MPs, RT nurses, and so on) in radiation oncology in Japan. The structure survey data presented and discussed here seemed to be both fundamental and important for a clear and accurate understanding of the medical care system for radiation oncology in Japan. As this survey data makes clear, a

Table 4 Primary sites of cancer, brain metastasis, and bone metastasis treated with RT in designated cancer care hospitals and the other radiotherapy hospitals

Primary site	DCCHs (n = 344)		Comparison with 2007[a]	Others (n = 300)		Comparison with 2007[a]	p value[b]	Total (n = 644)	
	n	%	%	n	%	%		n	%
Cerebrospinal	4,719	3.9	0.2	4,342	8.5	−1.1	<0.0001	9,061	5.8
Head and neck (including thyroid)	13,084	10.9	−0.2	5,021	9.8	2.4	<0.0001	18,105	9.8
Esophagus	7,306	6.1	−0.4	2,288	4.5	−0.6	<0.0001	9,594	6.0
Lung, trachea, and mediastinum	21,600	18.0	−0.6	10,707	21.0	−0.5	<0.0001	32,307	19.5
Lung	19,532	16.2	−0.6	9,659	18.9	0.7	<0.0001	29,191	17.3
Breast	27,706	23.0	1.4	12,128	23.8	2.3	0.0008	39,834	21.5
Liver, biliary, tract, and pancreas	4,733	3.9	−0.1	1,908	3.7	0.3	0.0577	6,641	3.8
Gastric, small intestine, and colorectal	5,693	4.7	−0.2	2,586	5.1	−0.4	0.0029	8,279	5.1
Gynecologic	6,851	5.7	0.0	1,365	2.7	−0.6	<0.0001	8,216	4.9
Urogenital	16,641	13.8	0.7	6,409	12.6	−0.2	<0.0001	23,050	13.0
Prostate	12,830	10.7	0.9	5,089	10.0	0.6	<0.0001	17,919	9.6
Hematopoietic and lymphatic	6,176	5.1	−0.3	1,773	3.5	−0.1	<0.0001	7,949	4.8
Skin, bone, and soft tissue	3,014	2.5	−0.1	1,079	2.1	−0.7	<0.0001	4,093	2.7
Other (malignant)	1,359	1.1	−0.2	582	1.1	−0.3	0.8388	1,941	1.4
Benign tumors	1,407	1.2	−0.3	813	1.6	−0.4	<0.0001	2,220	1.6
Pediatric < 15 years (included in totals above)	900	0.7	0.0	192	0.4	−0.1	<0.0001	1,092	0.6
Total	120,289	100.0	0.0	51,001	100.0	0.0		171,290[c]	100.0
Metastasis	(n = 365)			(n = 335)				(n = 700)	
Brain	10,361	6.9	−0.7	9,973	14.7	−1.0	<0.0001	20,334	10.4
Bone	19,293	12.8	−0.9	7,613	11.3	−2.3	<0.0001	26,906	13.6

[a] Comparison with the data of 2007, calculated using the formula: data of 2009 (%) – data of 2007 (%)

[b] χ^2 test

[c] Number of total new patients is different with these data, because no data on primary sites were reported by some facilities

national policy is needed to improve the establishment of DCCHs and overcome the shortage of personnel for cancer care.

Acknowledgments This study was supported by the Japanese Society for Therapeutic Radiology and Oncology and Grants-in-Aid for Cancer Research (H22-3rd Term Cancer Control-General-043 and H23-3rd Term Cancer Control-General-007) from the Ministry of Health, Labor and Welfare of Japan and by Grants-in-Aid for Scientific Research from the Japan Society for the Promotion of Sciences (No. 23591838). We would like to express our appreciation to all ROs and radiotherapy technologists throughout Japan who participated in this survey, for providing us with valuable information to make this study possible. This study was supported by JASTRO.

Conflict of interest The authors declare that they have no conflict of interest.

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Journal of Radiation Research, 2012, 53, 710–721
doi: 10.1093/jrr/rrs028 Advance Access Publication 5 July 2012

Japanese structure survey of radiation oncology in 2009 based on institutional stratification of the Patterns of Care Study

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(Received 25 March 2012; revised 4 May 2012; accepted 7 May 2012)

The ongoing structure of radiation oncology in Japan in terms of equipment, personnel, patient load and geographic distribution was evaluated in order to radiation identify and improve any deficiencies. A questionnaire-based national structure survey was conducted from March 2010 to January 2011 by the Japanese Society for Therapeutic Radiology and Oncology (JASTRO). These data were analyzed in terms of the institutional stratification of the Patterns of Care Study (PCS). The total numbers of new cancer patients and total of cancer patients (new and repeat) treated with radiation in 2009 were estimated at 201,000 and 240,000, respectively. The type and numbers of systems in actual use consisted of Linac (816), telecobalt (9), Gamma Knife (46), ^{60}Co remote afterloading system (RALS) (29) and ^{192}Ir RALS systems (130). The Linac systems used dual energy function for 586 (71.8%), 3DCRT for 663 (81.3%) and IMRT for 337 units (41.3%). There were 529 JASTRO-certified radiation oncologists (ROs), 939.4 full-time equivalent (FTE) ROs, 113.1 FTE medical physicists and 1836 FTE radiation therapists. The frequency of interstitial radiation therapy use for prostate and of intensity-modulated radiotherapy increased significantly. PCS stratification can clearly identify the maturity of structures based on their academic nature and caseload. Geographically, the more JASTRO-certified physicians there were in a given area, the more radiation therapy tended to be used for cancer patients. In conclusion, the Japanese structure has clearly improved during the past 19 years in terms of equipment and its use, although a shortage of manpower and variations in maturity disclosed by PCS stratification remained problematic in 2009.

Keywords: Structure survey; radiotherapy facility; radiotherapy personnel; radiotherapy equipment; caseload

INTRODUCTION

The medical care systems of the USA and Japan have very different backgrounds. In 1990, the Patterns of Care Study (PCS) conducted a survey of the structure of radiation oncology facilities in 1989 for the entire census of facilities in the USA [1]. In 1991, the Japanese Society for Therapeutic Radiation Oncology (JASTRO) conducted the first national survey of the structure of radiation therapy facilities in Japan based on their status in 1990, and the results were reported by Tsunemoto *et al.* [2]. The first comparison of these two national structure surveys to illustrate and identify similarities and differences in 1989–90 was conducted by the author and reported in 1996 [3]. The resultant international exchange of information proved especially valuable for Japan, where the structure of radiation oncology could be improved on the basis of those data.

The Japanese structure has gradually changed since a greater number of cancer patients are treated with radiation and public awareness of the importance of radiotherapy (RT) has grown. JASTRO has conducted national structure surveys every two years since 1990 [2] and every year since 2011. Furthermore, in 2006 the Cancer Control Act was approved in Japan, which strongly advocates the promotion of RT and an increase in the number of radiation oncologists (ROs) and medical physicists. The Japanese Ministry of Education, Sciences and Sports is supporting the education of these specialists at university medical hospitals. The findings of international comparisons and the consecutive structural data gathered and published by JASTRO have been useful for an understanding of our current position and future direction [4–7]. In this report, the recent structure of radiation oncology in Japan is analyzed and compared with the data of 2007 [6].

MATERIALS AND METHODS

From March 2010 to January 2011, JASTRO conducted a questionnaire based on the national structure survey of radiation oncology in 2009. The questionnaire dealt with the number of treatment systems by type, number of personnel by category and number of patients by type, site and treatment modality. To measure variables over a longer period of time, data for the calendar year 2009 were also requested. The response rate was 700 out of 770 (90.6%) of active facilities. The data from 241 institutions (31.3%) were also registered in the International Directory of Radiotherapy Centres (DIRAC) in Vienna, Austria in 2011.

The PCS was introduced in Japan in 1996 [8–17]. The Japanese PCS employed methods similar to those of the American version, which used structural stratification to analyze national averages for the data for each survey item by means of two-stage cluster sampling. For the regular structure survey, RT facilities throughout the country were stratified into four categories. This stratification was based on academic conditions and the annual number of patients treated with radiation at each institution, because academic institutions require and have access to more resources for education and training, while the annual caseload also constitutes essential information related to structure. For the study reported here, the following institutional stratification was used. A1: university hospitals/cancer centers treating 462 patients or more per year; A2: the same type of institutions treating 461 patients or fewer per year; B1: other national/public hospitals treating 158 patients or more per year; and B2: other national hospital/public hospitals treating 157 patients or fewer per year.

SAS 8.02 (SAS Institute Inc., Cary, NC, USA) [18] was used for statistical analyses and statistical significance was tested by means of the chi-squared test, Student's *t*-test or analysis of variance (ANOVA).

RESULTS

Current situation of radiation oncology in Japan

Table 1 shows that the numbers of new patients and total patients (new plus repeat) undergoing radiation in 2009 were estimated at 201 000 and 240 000, respectively, showing a 11.0% increase over 2007 [6], with 40% of the patients being treated at academic institutions (categories A1 and A2), even though these academic institutions constituted only 20% of the 700 radiotherapy facilities nationwide.

Cancer incidence in Japan in 2009 was estimated at 724 426 cases [19] with approximately 27.6% of all newly diagnosed patients treated with radiation. This number and corresponding rate have increased steadily over the last 19 years and is expected to increase further [14]. In 1990, the rate was estimated to be approximately 15% [3], and it was 16% in 1995, 17% in 1997, 20% in 1999, 22% in 2001, 23.3% in 2003 [4], 24.5% in 2005 [5], 26.1% in 2007 [6] and 27.6% in 2009.

Facility and equipment distribution patterns

Table 2 shows an overview of RT equipment and related functions. There were 816 Linac, 46 Gamma Knife, 29 ^{60}Co remote afterloading system (RALS), 130 ^{192}Ir and 1 ^{137}Cs RALS systems in actual use, as well as 9 of the 15 telecobalt systems installed. The Linac systems used dual energy function for 586 (71.8%), 3D conformal radiation therapy (3DCRT) for 663 (81.3%) and intensity-modulated radiation therapy (IMRT) for 337 units (41.3%). The IMRT function was employed more frequently for the equipment of academic institutions (A1: 73.4% and A2: 49.5%) than that of non-academic institutions (B1: 42.3% and B2: 18.1%). However, 3DCRT functions were disseminated widely in both academic and non-academic institutions, with 69% even in B2 institutions. The use of image-guided radiation

Table 1. PCS stratification of radiotherapy facilities in Japan

Institution category	Description	Facilities (*n*)	New patients (*n*)	Average new patients/facility[a] (*n*)	Total patients (new + repeat) (*n*)	Comparison with data of 2007[b] (%)	Average total patients/facility[a] (*n*)	Comparison with data of 2007[b] (%)
A1	UH and CC (≥462 patients/y)	70	52 078	744.0	62 124	2.9	887.5	4.3
A2	UH and CC (<462 patients/y)	70	18 842	269.2	22 717	3.9	324.5	5.4
B1	Other (≥158 patients/y)	280	84 938	303.4	101 730	8.0	363.3	11.1
B2	Other (<158 patients/y)	280	26,532	94.8	31 258	9.2	111.6	13.5
Total		700	182 390[c]	260.6	217 829[c]	6.2	311.2	9.4
						7.3		5.9

PCS = Patterns of Care Study; UH = university hospital; CC = cancer center hospital; Other = other national, city, or public hospital.
[a]$P < 0.0001$.
[b]Rate of increase compared with the data of 2007. Calculating formula: $\frac{data\ of\ 2009\ (n) - data\ of\ 2007(n)}{data\ of\ 2007(n)} \times 100\ (\%)$
[c]Number of radiotherapy institutions was 770 in 2009, and the number of new patients was estimated at approximately 201 000; the corresponding number of total patients (new plus repeat) was 240 000.

therapy (IGRT) has been steadily expanding from A1 institutions (30.4% to 33.5%) to the other types of institutions (14.0% to 35.5%). The annual numbers of patients/Linac were 393.2 for A1, 244.3 for A2, 339.1 for B1 and 118 for B2 institutions and showed a 9.8 % increase compared with the data from 2007. The number of institutions with telecobalt in actual use showed a major decrease to 9 and became stable compared with 2007. Gamma Knife was installed more frequently in B1 and B2 institutions. A significant replacement of ^{60}Co RALS with ^{192}Ir RALS was observed especially in academic institutions, while the number of new ^{60}Co RALS-type systems in use did not increase. Six particle machines were registered in this survey, two with carbon-beam and five with proton-beam irradiation. One machine in Hyogo Prefecture can deliver either carbon or proton beams. Although the HIMAC in Chiba Prefecture has two synchrotrons, it was registered as one machine in the 2009 survey. The total number of new cancer patients treated at these six institutions was estimated at 2038 (1.19% of all new patients in Japan). Twenty-seven advanced institutions were included in the A1 category and treated more than 800 patients per year. They were equipped with Linacs with dual energy (75.3% of the institutions), 3DCRT (97.2%) and IMRT function (82.2%), as well as with ^{192}Ir RALS (92.6%) and a computed tomography (CT) simulator (96.3%).

Table 3 shows an overview of RT planning and other equipment. X-ray simulators were installed in 51.6% of all institutions, and CT simulators in 82.1%, with the latter exceeding the former for the first time in 2007. There was a significant difference in the rate of CT simulators installed by institutional stratification, from 95.7% in A1 to 69.3% in B2 institutions. Very few institutions (16 institutions) used magnetic resonance imaging (MRI) for RT only, while computers were widely used for RT recording.

Staffing patterns and patient loads

Table 4 shows the staffing patterns and patient loads by institutional stratification. 'Full-time or part-time' refers to the style of employment. Since even full-time ROs must share the diagnosis in a week at smaller institutions such as found in the B2 category, we felt that these numbers were not adequate for an accurate evaluation of man power. Therefore, data for full-time equivalent (FTE: 40 h/week for radiation oncology service only) were assessed in terms of the clinical working hours in RT of each individual. This is thus a method to determine actual man power at each institution. The total number of FTE ROs in Japan stood at 939.4, while the average numbers were 4.6 for A1, 1.6 for A2, 1.3 for B1 and 0.6 for B2 institutions. The number in B1 improved by 30% compared with 2007 [6]. The overall patient load per FTE RO in Japan was 231.9, and for A1, A2, B1 and B2 institutions the loads were 193.5, 205.2, 290.6 and 198.4, respectively, with the patient load for B1 institutions being by far the highest. The increase in the overall patient load per

Table 2. Equipment, its function and patient load per equipment by PCS institutional stratification

Radiotherapy equipment and its function	A1 (*n* = 70)		A2 (*n* = 70)		B1 (*n* = 280)		B2 (*n* = 280)		Total (*n* = 700)		Comparison with data of 2007 (%)
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	
Linear accelerator	158		93		300		265		816		1.1[a]
with dual energy function	122	*77.2*[b]	70	*75.3*[b]	235	*78.3*[b]	159	*60.0*[b]	586	*71.8*[b]	5.0[c]
with 3DCRT function (MLC width ≥1.0 cm)	150	*94.9*[b]	81	*87.1*[b]	247	*82.3*[b]	185	*69.8*[b]	663	*81.3*[b]	12.5[c]
with IMRT function	116	*73.4*[b]	46	*49.5*[b]	127	*42.3*[b]	48	*18.1*[b]	337	*41.3*[b]	12.2[c]
with cone beam CT or CT on rail	48	*30.4*[b]	33	*35.5*[b]	73	*24.3*[b]	41	*15.5*[b]	195	*23.9*[b]	
with treatment position verification system (X-ray perspective image)	51	*32.3*[b]	31	*33.3*[b]	85	*28.3*[b]	37	*14.0*[b]	204	*25.0*[b]	
with treatment position verification system (other than those above)	53	*33.5*[b]	18	*19.4*[b]	77	*25.7*[b]	55	*20.8*[b]	203	*24.9*[b]	
Annual no. patients/Linac	393.2[d]		244.3[d]		339.1[a]		118.0[d]		266.9[d]		9.8[a]
Particle	3		0		3		0		6		
Microtoron	6		2		3		4		15		
Telecobalt (actual use)	2 (0)		2 (0)		3 (1)		8 (7)		15 (9)		
Gamma knife	3		2		32		9		46		
Other accelerator	2		1		1		1		5		
Other external irradiation device	4		2		1		0		6		
New type ^{60}Co RALS (actual use)	4 (4)	5.7[e] (5.7)	1 (1)	1.4[e] (1.4)	9 (9)	3.2[e] (3.2)	2 (1)	0.7[e] (0.4)	16 (15)	2.3[e] (2.1)	
Old type ^{60}Co RALS (actual use)	2 (2)	2.9[e] (2.9)	2 (1)	2.9[e] (1.4)	14 (11)	5.0[e] (3.9)	4 (0)	1.4[e] (0.0)	22 (14)	3.1[e] (2.0)	
^{192}Ir RALS (actual use)	60 (60)	85.7[e] (85.7)	32 (31)	45.7[e] (44.3)	37 (37)	13.2[e] (13.2)	4 (2)	1.4[e] (0.7)	133 (130)	19.0[e] (18.6)	
^{137}Cs RALS (actual use)	1 (0)		0 (0)		1 (1)		0 (0)		2 (2)		

PCS = Patterns of Care Study; RT = radiotherapy; 3D-CRT = three-dimensional conformal radiotherapy; MLC = multileaf collimator; IMRT = intensity-modulated radiotherapy; RALS = remote-controlled after-loading system.

[a]Rate of increase compared with the data of 2007. Calculating formula: $\frac{data\ of\ 2009\ (n) - data\ of\ 2007\ (n)}{data\ of\ 2007\ (n)} \times 100\ (\%)$

[b]Percentage calculated from the number of systems using this function and the total number of linear accelerator systems.

[c]Comparison with the data of 2007. Calculating formula: *data of* 2009 (%) − *data of* 2007 (%)

[d]The number of patients over the number of linear accelerators; institutions without linear accelerators excluded from calculation.

[e]Rate of institutions that have this equipment (≥2 pieces of equipment per institution).

Table 3. Radiotherapy planning and other equipments by PCS institutional stratification

RT planning and other equipment	A1 (n = 70)		A2 (n = 70)		B1 (n = 280)		B2 (n = 280)		Total (n = 700)		Comparison with data of 2007[b] (%)
	n	%[a]	n	%[a]	n	%[a]	n	%[a]	n	%[a]	
X-ray simulator	55	74.3	41	55.7	130	46.1	135	48.2	361	50.7	−10.2
CT simulator	74	95.7	61	84.3	235	78.6	205	69.3	575	77.1	11.5
RTP computer (two or more)	340 (63)	100 (90.0)	167 (35)	100 (50.0)	461 (99)	97.5 (35.4)	303 (37)	92.5 (13.2)	1271 (234)	96.0 (33.4)	0.7 (10.1)
MRI (two or more)	201 (60)	95.7 (85.7)	151 (56)	98.6 (80.0)	504 (184)	97.5 (65.7)	364 (86)	97.9 (30.7)	1220 (386)	97.6 (55.1)	1.8 (3.8)
for RT only	2	2.9	2	2.9	9	2.9	3	1.1	16	2.1	0.6
Computer use for RT recording	64	91.4	65	92.9	264	94.3	238	85.0	631	90.1	1.3

CT = computed tomography; RTP = radiotherapy planning; MRI = magnetic resonance imaging; other abbreviations as in Table 2.
[a]Ratio of institutions that have equipment (≥2 pieces of equipment per institution).
[b]Comparison with the data of 2007. Calculating formula: *data of 2009 (%) − data of 2007 (%)*.

FTE RO was 13.7% compared with 2007 (6). In Japan, 42.6 % of the institutions providing RT have their own designated beds, where ROs must also take care of their in-patients. The percentage distribution of institutions by patient load per FTE RO shown in Fig. 1a indicates that the largest number of facilities featured a patient/FTE staff level in the 101–150 range, and in the 151–200 range for the second largest number. The blue areas of the bars show that 47.7% of the institutions (334/700) had less than one FTE RO. Compared with 2007 [6], the patient load has increased even more.

A similar trend was observed for RT technologists and their patient load by institutional stratification with the percentage distribution of institutions by patient load per radiation technologist displayed in Fig. 1b. The largest number of facilities had a patient-per-radiotherapy technologist level in the 101–120 range, with the second largest number showing a range of 81–100 and the third largest a range of 121–140. There were 113.1 FTE medical physicists, 113.1FTE radiotherapy quality assurance (QA) staff and 1836FTE radiotherapists. For this survey, personnel numbers were checked for duplicate reporting by identification of individuals on staffing data and these data were analyzed in detail in another report [7]. Finally, there were 621.2 FTE nurses.

Distribution of primary sites, specific treatment and palliative treatment

Table 5 shows the distribution of primary sites by institutional stratification. The most common disease site was the breast, followed by the lung/bronchus/mediastinum and genito-urinary region. In Japan, the number of patients with prostate cancer undergoing RT was 17 919 in 2009, showing an increase of 10.4% over 2007 [6]. By disease site, the rate of increase compared with 2007 was the highest for prostate cancer at 10.4%, the second highest for breast cancer at 9.6% and the third highest for head and neck cancer at 9.3%. The stratification of institutions indicates that the rate of increase for lung cancer was notable for A1 institutions and the rates for prostate cancer were high for all categories, ranging from 8.0–20.3%. On the other hand, the rate for breast cancer was the lowest (–0.7%) for A2, while those for B1 and B2 ranged from 11.8–18.8%, and the rates for head and neck cancer were high for A2 (17.7%) and B1 (21.4%).

Table 6 shows the distribution of use of specific treatments and the number of patients treated with these modalities by PCS stratification of institutions. Use of interstitial irradiation, radioactive iodine therapy for prostate cancer, stereotactic body RT, IMRT and hyperthermia increased by 23.3%, 14.5%, 4.9%, 34.8% and 15%, respectively, compared with 2007 [6]. On the other hand, the use of intraoperative RT decreased significantly by –31.1%. Institutional stratification shows that there was a dramatic increase of 454.1% in the use of IMRT in B2 [5]. In 2009,

Table 4: Structure and personnel by PCS institutional stratification

	Structure and personnel					
	A1 ($n = 70$)	**A2** ($n = 70$)	**B1** ($n = 280$)	**B2** ($n = 280$)	**Total** ($n = 700$)	**Comparison with data of 2007 [a] (%)**
Institutions/total institutions (%)	10.0	10.0	40.0	40.0	100	-
Institutions with RT bed (n)	59 (84.3)	37 (52.9)	124 (44.3)	78 (27.9)	298 (42.6)	6.0 (3.6 [b])
Average RT beds/institution (n)	11.2	3.3	3.1	1.5	3.3	6.5
Number of ROs (full time + part time)	369 + 64	151 + 35	372 + 216	193 + 245	1085 + 560	6.7
JASTRO-certified RO (full time)	214	73	192	52	531	11.3
Average JASTRO-certified RO/institution (n)	3.1	1.0	0.7	0.2	0.8	14.2
Total (full-time and part-time) RO FTE*	321.1	110.7	350.1	157.5	939.4	13.7
Average FTE ROs/institution	4.6	1.6	1.3	0.6	1.3	18.2
Patient load/FTE RO	193.5	205.2	290.6	198.4	231.9	-6.7
Number of RT technologists (full time + part time)	492 + 22	280 + 13	1133 + 33	825 + 2	2730 + 70	4.4
Total (full-time and part-time) RT technologist FTE	434.3	206.8	758.6	436.2	1836.0	12.4
Average FTE RT technologists/institution	6.2	3.0	2.7	1.6	2.6	13.0
Patient load/FTE RT technologist	143.0	109.9	134.1	71.7	118.6	-5.5
Number of full-time nurse (full time + part time)	114 + 26	74 + 13	270 + 82	125 + 50	583 + 171	-37.1
Total (full-time and part-time) nurse FTE	135.4	68.7	290.4	126.8	621.2	25.6
Number of medical physicists (full time + part time)	70 + 5	27 + 2	125 + 10	65 + 5	287 + 22	10.8
Total (full-time and part-time) medical physicist FTE	32.3	8.7	54.4	22.0	117.6	71.9
Number of RT QA staffs (full time + part time)	79 + 0	52 + 0	174 + 3	85 + 3	390 + 6	-26.1
Total (full-time and part-time) RT QA staff FTE	25.8	15.2	50.3	25.0	116.3	9.1

JASTRO = Japanese Society of Therapeutic Radiation Oncology; RO = radiation oncologist; FTE = full-time equivalent (40 h/wk only for RT practice); QA = quality assurance; other abbreviations as in Table 2. RT QA staff: Japanese Organization of RT Quality Management has certified RT quality managers from RT technologist since 2005 mainly by educational session.Data in parentheses are percentages.

[a]Rate of increase compared with the data of 2007. Calculating formula: $\frac{data\ of\ 2009\ (n) - data\ of\ 2007\ (n)}{data\ of\ 2007\ (n)} \times 100\ (\%)$

[b]Comparison with the data of 2007. Calculating formula: $data\ of\ 2009\ (\%) - data\ of\ 2007\ (\%)$

101 institutions (14.4%) actually utilized IMRT, which was significantly lower than the 337 Linacs with IMRT function (41.3%) as shown in Table 2. Figure 2 lists the numbers of patients treated with SRT and IMRT for each survey year. Approximately 12 000 patients were treated with SRT for the brain in each survey year and this number has remained stable. On the other hand, the number treated with SRT for the rest of the body has been increasing gradually and exceeded 2000 in 2009. The corresponding number of patients for IMRT has been increasing more rapidly and exceeds 4000, or about 2% of all RT-treated patients in 2009.

Table 7 shows the number of patients with brain or bone metastasis treated with radiation according to the same institutional stratification. More patients with brain metastasis (12.2% of all patients) were treated at B1 than at the other types of institutions, while use of radiation for bone