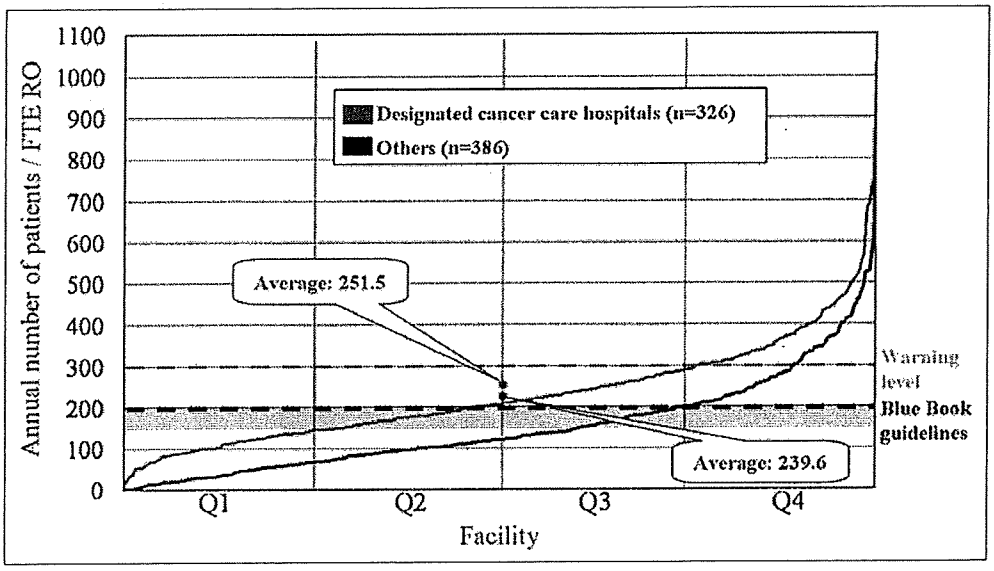

Fig. 1　Distribution of annual patient loads/FTE radiation oncologist in designated cancer care hospitals and other radiotherapy facilities. Horizontal axis represents facilities arranged in order of increasing value of the annual number of patients/FTE radiation oncologist within the facilities.

は，結局カルテを取り寄せたり，診療端末(HIS)上でデータを参照する必要があるのが現状である．これらは，さらにDBへの情報入力のモチベーションを下げる要因となっている．いくら優れたDBを構築しても，正確な情報が入力されなければ無意味である．

放射線治療の装備については整備改善が徐々に進んできているが，マンパワー不足はいまだにあまり改善されていない[4)-6)]．2005年の構造調査時点では，IMRTが可能なリニアックのうち，実際にIMRTが施行されていたのはわずか6%であり，マンパワー不足がその最大の要因であるものと思われた[7)]．

このマンパワー不足による放射線腫瘍医の加重な負担を解消するためには，放射線腫瘍医の増員が根本的な解決法として最も望まれるが，別のアプローチとして，JASTROデータベース委員会やIHE-J ROの活動などによって，放射線治療部門のワークフローの標準化が進めば，上記の各システム間のデータ連携などの問題が解消され，情報の共有化が可能となり，放射線腫瘍医の負担を軽減できるという方法も考えられる．その意味で今後もJASTROとしてIHE-J ROの活動を支援し，連携をとって活動を続けていくこととしている．

がん登録は，がんに関する情報を収集し，解析するためのシステムであるが，地域がん登録，院内がん登録，臓器別がん登録の3タイプに分けられる[10)]．これらは，それぞれ目的や役割が異なっている．日本においては，地域がん登録が1950年代から主に県単位で開始され，1992年に地域がん登録全国協議会が発足した[11)]．2007年現在，全国47のうちの35都道府県と1市において登録が行われている．

法的な強制力はないこともあって，すべての地方自治体で施行されているわけではないが，がんの罹患率の推計や生存率の集計に役立てられている．院内がん登録は，現在は限られた病院でのみ行われているのが現状であるが，がん診療連携拠点病院においては，その登録が義務化されている．がん診療連携拠点病院が診療を行っているがん患者の割合は県によって異なると考えられ，70%程度を担当していると思われる県もあれば，25%程度にとどまっている地方自治体もあるとされている[10)]．臓器別がん登録は，特定の臓器がんにおいて，学会や研究グループレベルで登録が行われているものであり，他の2つと比較すると，より詳細なデータが集積されている[10)]．これらのがん登録間では，院内がん登録から地域がん登録へは情報の流れがあるが，臓器別がん登録とは情報の連携がなされていない．また，地域がん登録の中でも，登録内容の標準化が十分に進んでいないという問題も指摘されている．

米国では，National Cancer Database(NCDB)が1989年から開始され，現在では米国内の1,430以上の病院から新規がん患者の約70%(年約94万人)が登録されており，これまでに2,100万人分以上のデータが蓄積されている世界最大規模のがん登録データベースである[12)]．データは各施設の認定腫瘍登録士がまとめて提出し，QAチェックを受けている．このNCDBを用いた多数の研究論文が発表されており，がんの疫学から治療法の傾向，治療成績，癌治療の品質指標の確立など，幅広い分野にわたって役立てられており，がん治療の質の向上に貢献している．

日本の放射線治療の分野に関しては，前記のJASTROによる構造調査が行われており，また，診療内容や治療成績

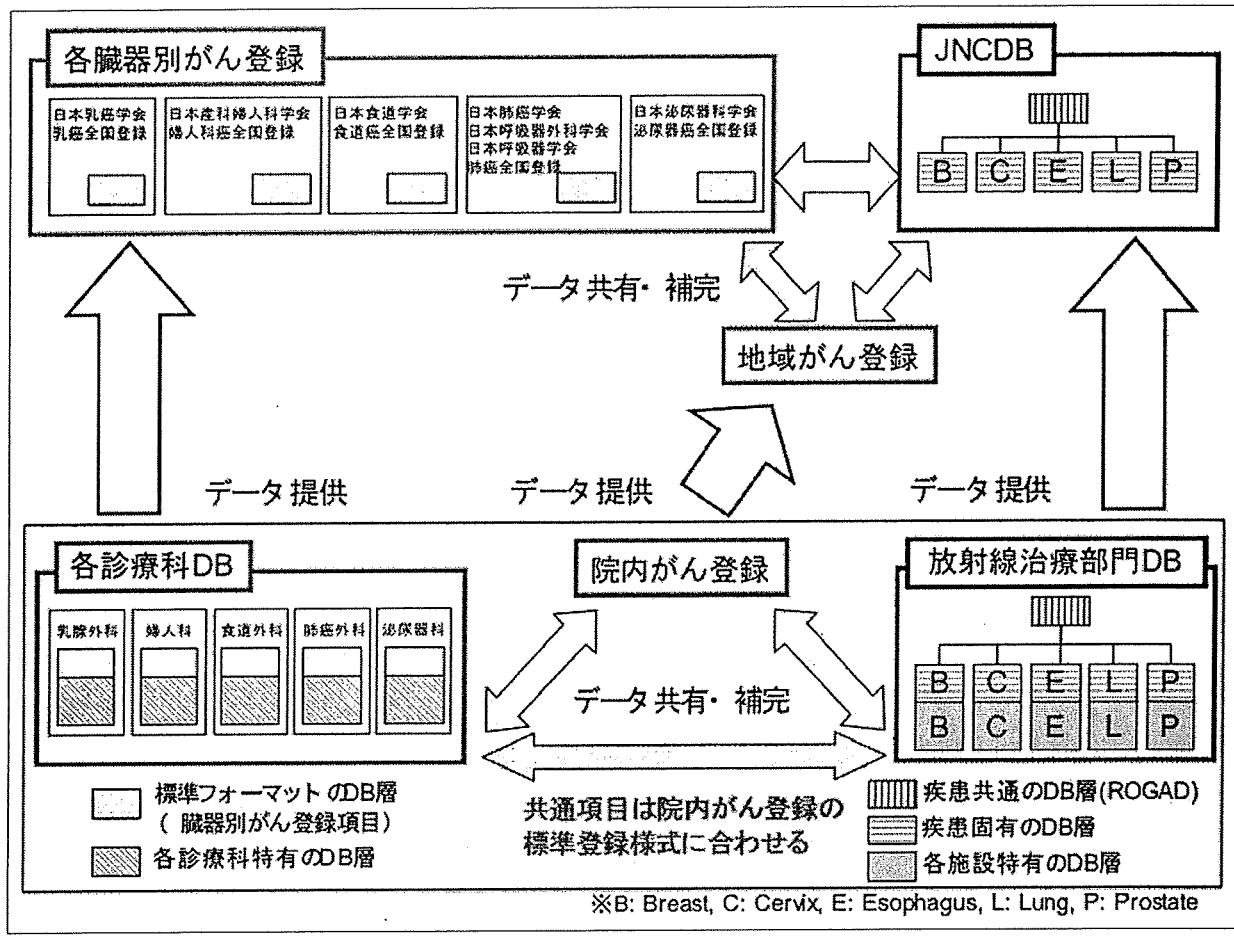

Fig. 2　Future direction of cancer registration system and cancer database system.

についてもPatterns of Care Study(PCS)である程度調査されているが[13]，十分な治療成績の情報を集積した調査としてのNCDBのようなものが，まだ整備されていない．NCDBは，がん治療のprocessとoutcomeの改善のためのquality indicatorとして使われている．現在，手島班においてJapanese National Cancer Database(JNCDB)を構築する準備が進められている[7]．Fig. 2にJNCDBを含めた各がん登録間の連携についての将来構想を示す．放射線治療部門は臓器横断的にデータを持っているため，他のがん登録や各施設の診療科DBと情報をうまく共有できれば，質の高いデータが各登録で補完できると考えられる．この中で，診療科DBや部門DBに関しては，IHE-J ROおよびJASTROデータベース委員会と連携して議論が行われており，より良いDBを提供できるように今後も改訂を継続していく予定となっている．

IHE-J ROの整備やJASTROデータベース委員会の活動等により，各システム間の連携，情報の共有がうまく行われるようになり，さらには，その情報が臓器別がん登録やJNCDBといった形で，全国的に集計，解析され，単なる疫学調査にとどまらず，治療成績の評価にもつながるようなシステムが構築されれば，DB入力の意義を実感できるようになるであろう．臨床家のために役立つ全国的がん診療評価システムの構築実現が望まれる．

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要旨：放射線治療に関する情報をどのように入力，管理，運用し，さらに有効活用していくかについては，まだまだ問題が多い．当院では，以前から放射線治療部門データベース(部門DB)が構築運用されていたが，実質上管理が困難な状態となり，Filemakerベースの DBに再構築した．現状に合わなくなったテーブルや項目を割愛したり，放射線治療広域データベースROGADに含まれる項目を加えたりすることにより，JASTROの構造調査への対応や，将来の全国規模のデータ収集への対応も可能となることを目指した．しかし，実際にはデータの入力もれや，入力方法の誤りなどのために，今回のJASTRO構造調査に対応した正確なデータを抽出することはできなかった．また，当院では，放射線治療に関するRISが更新され，その入力が必須となったが，部門DBとの連携がなく，情報入力の負担が増えている．がん診療連携拠点病院に指定され，院内がん登録も本格的に開始されたが，やはり部門DBとの連携がない状況である．このように当院内だけにおいても，情報の共有が行われておらず，現場の負担は増え続けている．この状況で情報入力が義務化されても，その意義を感じられなければ，実際の情報入力者である担当医のモチベーションは下がり，情報の正確性が低下してしまうという悪循環に陥りかねない．IHE-J ROの整備やJASTROデータベース委員会の活動等により，各システム間の連携，情報の共有がうまく行われるようになり，さらには，その情報が臓器別がん登録やJNCDB(Japanese National Cancer Database)といった形で，全国的に集計，解析され，単なる疫学調査にとどまらず，治療成績の評価にもつながるようなシステムが構築されれば，DB入力の意義を実感できるようになるであろう．臨床家のために役立つ全国的がん診療評価システムの構築実現が望まれる．

放射線治療最前線

II　がん治療の臨床最前線：放射線治療を中心に

1．頭頸部がん
――わが国の局所進行頭頸部がんに対するCRTの現状

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本稿では，局所進行頭頸部扁平上皮癌に対する化学放射線療法（chemo radiotherapy：CRT）に関する最近のトピックや問題点について，東京大学医学部附属病院（以下，東大病院）およびわが国の現状を交えて記す。

シスプラチン単剤か？多剤併用か？

局所進行頭頸部扁平上皮癌の根治的放射線療法において，化学療法を同時併用することにより，放射線単独療法と比較して局所制御率および生存率が向上することが多くのランダム化比較試験やメタアナリシスで証明されている[1)~10)]。

放射線療法と同時併用する化学療法として，シスプラチン（CDDP）単剤レジメン[1)~4)]およびCDDP＋フルオロウラシル（5-FU）などCDDPを含んだ多剤併用レジメン[5)~9)]の双方にて，放射線単独療法と比較した際の生存率の向上が多数報告されている。

CDDP単剤レジメンと多剤併用レジメンの優劣に関して厳密に比較した臨床試験は存在しないが，メタアナリシスでは両者の効果に有意差は認めず[11)]，多剤併用レジメンでは有害事象が増加することから（特に5-FUを併用した場合には粘膜炎の増悪が著明である）[12)~14)]，現在の標準レジメンは，CDDP 100 mg/m^{2}を3週ごとに3回静脈内投与をし，放射線療法と同時併用する高用量CDDP単剤レジメンであり[13),15)]，Radiation Therapy Oncology Group（RTOG）が企画する臨床試験の標準治療群にはこのレジメンが用いられている。

しかし，わが国において高用量CDDP単剤レジメンはほとんど定着していない。この理由は主として“そのような高用量のCDDPは日本人の許容量を超えている”という認識にあり[16)]，この結果，CDDPを70～80 mg/m^{2}程度，あるいはそれ以下まで減量して，5-FUを併用したレジメンを用いる施設が多数派である。東大病院でも高用量CDDP単剤レジメンの実施経験はなく，CDDP＋5-FUのレジメンを用いることが多い。また，タキサン系抗がん剤や動注化学療法を用いる施設も散見され，世界的に標準とされるレジメンがほとんど実施されないままに，施設ごとにさまざまなレジメンが乱立しているのが現状である。

この現状を受けて，Zendaらは，高用量CDDP単剤レジメンに対する日本人のコンプライアンスを検討するために多施設共同臨床試験を実施した[17)]。すなわち，20人の局所進行頭頸部がんに対し，70 Gy/35回の放射線療法とCDDP 100 mg/m^{2}を3週ごとに3回同時併用するレジメンにてCRTを施行したところ，治療完遂率は85％であった。Zendaらは，日本人においても高用量CDDP単剤レジメンは十分に施行可能であり，これまで日本人で高用量のCDDPに対して低いコンプライアンスが報告されてきたのは人種差の問題ではなく，医療従事者の技術の問題だと述べている。

Zendaらの報告を受けて，今後わが国においても高用量CDDP単剤レジメンが普及することを期待したい。

通常分割か？過分割か？加速過分割か？

化学療法同時併用における放射線療法の照射分割法としては，現時点では1日1回，1回2Gyの通常分割法にて総線量は70 Gyを用いるのが標準である[13),15),18)]。東大病院でも，放射線単独療法の場合は積極的に過分割照射あるいは加速過分割照射を用いているが，化学療法同時併用では原則70 Gy/35回/7週としている。放射線療法の休止を挟むスプリットコースレジメンは，局所制御率および生存率を低下させることが報告されており[2)]，推奨されない。

過分割照射あるいは加速過分割照射を用いることにより，さらなる治療成績の向上が得られるかどうかを検証するために，RTOGによりランダム化比較試験が実施された。すなわち，局所進行頭頸部がんに対し，標準分割群（70 Gy/35回/7週，CDDP 100 mg/m^{2}を3週ごとに3回同時併用）と加速過分割照射群（72 Gy/42回/6週，後半は同日内ブースト法を用いた1日2回照射，CDDP 100 mg/m^{2}を3週ごとに2回同時併用）との比較試験（RTOG 0129）である[19)]。RTOG 0129は，すでに登録が終了し現在解析中であり，結果報告が待たれる。

見直される導入化学療法：TPF

従来より，CDDP＋5-FUによる導入

〈0913-8919/09/¥300/論文/JCLS〉

化学療法により高い奏効率および遠隔転移を減少させる効果が得られることは知られていたが，生存率の改善はほとんど見られず[10]，頭頸部がんにおける導入化学療法は標準治療としては用いられなくなっていた。しかし，近年のCRTの進歩に伴い，局所制御率が飛躍的に向上し，長期の生存例が増加したため遠隔転移が増加するという，再発様式の変化が明らかとなってきた。遠隔転移の出現を減少させるという目的のもとに，CDDP，5-FUにタキサン系抗がん剤を加えたTPFと呼ばれる3剤併用レジメンによる強力な導入化学療法が注目されている[18),20),21)]。

すでに複数のランダム化比較試験において，導入化学療法としてのTPFの有効性および安全性が証明されている[22),23)]。HittらはⅢ/Ⅳ期の局所進行頭頸部がんを対象に，導入化学療法としてTPF群（パクリタキセル175mg/m^2＋CDDP 100mg/m^2＋5-FU 500mg/m^2，5日）とFP群（CDDP 100mg/m^2＋5-FU 1000mg/m^2，5日）の2群に振り分け，導入化学療法3コース後に，CDDP 100mg/m^{2}を3週ごとに3回同時併用にてCRT（70Gy/35回）を施行し，TPF群において生存率が良好な傾向を認めた（2年生存率：TPF群66％ vs. FP群54％，p＝0.06）。また，粘膜炎の発生率に関しては，導入化学療法中はグレード2以上がTPF群で16％，FP群で53％（p＜0.001），CRT中はグレード3以上がTPF群で34％，FP群で55％（p＝0.004）と，TPF群で著明に少なかった[22)]。

導入化学療法を施行することにより，その効果から放射線療法への感受性を予測できるという利点もある。上記のHittらの試験では，非奏効例はすぐにはCRTを施行せず，頸部リンパ節転移における非奏効例であれば頸部郭清を先行し，原発巣における非奏効例は臨床試験から除外され，その後の治療法は担当医の判断に委ねられている[22)]。

東大病院でも，手術あるいはCRTのどちらで治療するか悩ましい症例に対しては，TPF（ドセタキセル70mg/m^2＋CDDP 70mg/m^2＋5-FU 700mg/m^2，5日）を用いた導入化学療法を施行し，奏効すればCRT，非奏効なら手術と，導入化学療法に対する反応で治療方針を決定している。また，切除不能症例に対しても治癒率の向上を目的に，積極的にTPFによる導入化学療法を行っている。

現在，TPFを用いた導入化学療法＋同時CRT vs. 同時CRTによるランダム化比較試験が行われており，今後TPFを用いた導入化学療法が標準治療となる可能性がある。

放射線療法を中断しないために——求められる急性期有害事象管理技術の向上

化学放射線同時併用療法では，放射線単独療法と比較して，急性期あるいは晩期の有害事象が格段に増加する[15)]。粘膜炎などの急性期有害事象が重篤化し，放射線療法の中断が余儀なくされるようであれば，治療効果の低下は免れない。したがって，化学放射線同時併用療法を施行する医療者は，急性期有害事象に対して早期から積極的に対処し，放射線療法の中断を防ぐために最大限の努力をしなければならない[15),17)]。

前述のZendaらの臨床試験では，治療開始前の内視鏡下経皮的胃瘻（percutaneous endoscopic gastrostomy：PEG）の設置を推奨し，20例中19例にてPEGを設置している[17)]。PEGを用いることにより，粘膜炎や嚥下困難により経口摂取が不可能となった場合にも，十分な栄養管理が可能となる。東大病院でも積極的にPEGを設置しており，中心静脈カテーテル管理と比較して感染などのトラブルが少なく，また，PEGを設置したまま在宅ケアへ移行できるため，入院期間の短縮にも貢献している。さらにZendaらは，高容量CDDPによる腎毒性を考慮して，腎毒性を助長する可能性のある非ステロイド系消炎鎮痛剤（NSAIDs）の使用は避けて，オピオイドを中心とした疼痛管理を推奨している[17)]。

そのほか，口腔ケアの重要性も認識するべきである[12)]。治療開始前から，歯科あるいは口腔外科に相談し，口腔ケアを進めるのが望ましい。

IMRT

頭頸部がんの放射線治療において強度変調放射線治療（intensity-modulated radiation therapy：IMRT）が有効であることはすでにコンセンサスがあり，わが国でも2008年4月より保険適用となっている。IMRTでは，病巣に十分な線量を投与しつつ，耳下腺，脊髄，脳，咽頭収縮筋，口腔，眼球などのリスク臓器への線量を減らすことが可能となる。またIMRTでは，標的体積内の線量勾配をつくることが可能であり，巨大病巣や低酸素腫瘍に対してより高線量を投与することもできる。

IMRTでは，高い自由度を持って空間線量分布を作成することができるため，治療計画時の輪郭入力の精度がそのまま治療成績に直結する[24)]。すなわち放射線腫瘍医には，腫瘍の進展範囲およびリンパ節領域やリスク臓器の解剖構造に対して，これまで以上に詳細な理解が要求される。腫瘍の進展範囲をより正確に同定するために，CT画像に加えてMR画像やPET画像を参照することが推奨される。リンパ節領域の輪郭に関しては，RTOGなどで作成されたCTアトラスがインターネットで公開されており，参考にできる[25)]。また，治療期間中の体格変化や病巣の縮小に伴い，IMRTでは線量分布が大きく変化する危険があり，治療期間中に何度か治療計画を作り直すなどの対応が求められる。

東大病院では，2003年3月より再放射線治療症例や頭蓋内浸潤を有する上咽頭がん症例などを対象に頭頸部がんのIMRTを開始し，その後の装置更新やマンパワーなどの関係でいったんは休止していたが，医学物理専門員の強力なサポートを得て，2008年7月より頭頸部がんに対するIMRTの実施を再開している（図1）。毎回の治療実施時に治療装置上でコーンビームCT（CBCT）を撮影し，治療計画用CTと骨基準で位置を照合している（図2）。CBCTを用いて照合することで，治療計画の変更が必要となるような体格や病巣サイズの変化が把握しやすい。

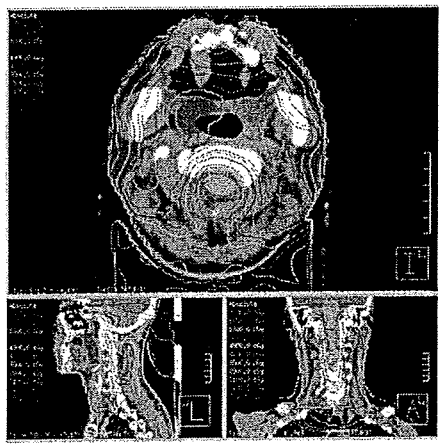

図1　IMRTの空間線量分布：中咽頭左側壁がん（T2N2c）症例

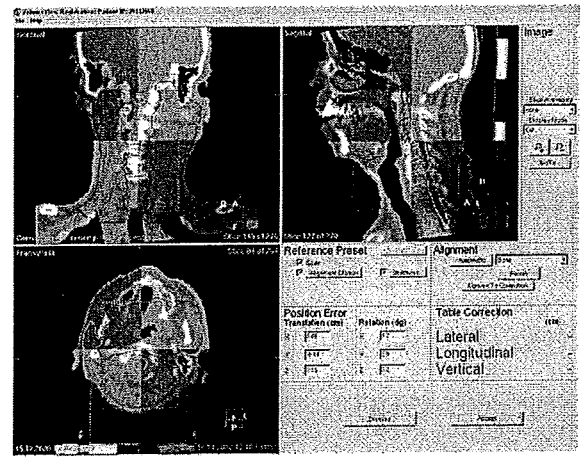

図2　CBCTを用いた位置照合

◎

CRTの進歩に伴い，治療にかかわる医師にはより高度な知識，技術が要求されている。放射線腫瘍医や頭頸部腫瘍医がさらなる努力を続けねばならないのはもちろんだが，私見ではあるものの，質の高い頭頸部CRTを提供するためには，腫瘍内科医の関与の必要性を強く感じる。わが国において，現時点で頭頸部がんの治療に腫瘍内科医がかかわっている施設はごくわずかであろうし，東大病院においても残念ながら腫瘍内科医の頭頸部がん治療への参加はなく，腫瘍内科医のサポートが得られないことが，前述の高用量CDDP単剤レジメンの施行に踏み切れない一因となっている。

今後，多くの腫瘍内科医が，頭頸部がんを熟知した上で中心となってCRTに携わる時代が到来し，わが国の頭頸部がん治療に飛躍的なレベルアップがもたらされることを期待したい。

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Risk Factors for Severe Dysphagia after Concurrent Chemoradiotherapy for Head and Neck Cancers

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Original Articles

Risk Factors for Severe Dysphagia after Concurrent Chemoradiotherapy for Head and Neck Cancers

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Objective: The aim of this study was to investigate the risk factors for dysphagia induced by chemoradiotherapy for head and neck cancers.
Methods: Forty-seven patients with head and neck cancers who underwent definitive chemoradiotherapy from December 1998 to March 2006 were reviewed retrospectively. Median age was 63 years (range, 16–81). The locations of the primary lesion were as follows: larynx in 18 patients, oropharynx in 11, nasopharynx in 7, hypopharynx in 7 and others in 4. Clinical stages were as follows: Stage II in 20 and Stages III–IV in 27. Almost all patients underwent platinum-based concomitant chemoradiotherapy. The median cumulative dose of cisplatin was 100 mg/m^2 (range, 80–300) and median radiation dose was 70 Gy (range, 50–70).
Results: Severe dysphagia (Grade 3–4) was observed in 22 patients (47%) as an acute toxic event. One patient required tube feeding even at 12-month follow-up. In univariate analysis, clinical stage (III–IV) ($P = 0.017$), primary site (oro-hypopharynx) ($P = 0.041$) and radiation portal size (>11 cm) ($P < 0.001$) were found to be associated with severe dysphagia. In multivariate analysis, only radiation portal size was found to have a significant relationship with severe dysphagia ($P = 0.048$).
Conclusions: Larger radiation portal field was associated with severe dysphagia induced by chemoradiotherapy.

Keywords: toxicity – combined modality therapy – head and neck neoplasm – dysphagia – radiotherapy

INTRODUCTION

Prospective randomized clinical trials showed that chemoradiotherapy is superior to radiotherapy alone for patients with advanced nasopharyngeal carcinoma (1). This combined therapy is now widely used in treatment of patients with head and neck cancers. A meta-analysis conducted by Pignon et al. (2) showed a significant benefit of concurrent chemoradiotherapy, which corresponded to an absolute 5-year overall survival benefit of 8% compared with radiotherapy alone in head and neck cancers. Indication of conventional radiation-alone therapy is confined to T1 and favorable T2, N0–1 tumors. Altered fractionation alone may be indicated for unfavorable T2, N0–1 tumors (3), but more advanced and operative head and neck cancers are usually treated by surgery followed by radiotherapy or chemoradiotherapy. Patients in whom surgery is contraindicated are treated by chemoradiotherapy. This therapy is sometimes used for operative patients who wish to preserve their organs.

Concomitant addition of chemotherapy to radiotherapy not only improves the outcome but also increases toxicity of the treatment. Various toxic events, such as pain, dysgeusia, and dysphagia, are intensified. Rosenthal et al. (4) reported that 40–70% of the patients undergoing concomitant chemoradiotherapy for head and neck cancers experienced severe mucositis and 50–80% required feeding tube placement during the course of therapy. Severe dysphagia arising during the course of therapy sometimes reduces the patients' quality of life and worsens their physical condition.

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Table 1. Patients' characteristics

Characteristics	Number of patients
Gender	
Male	41
Female	6
Age	16–81 (median, 63)
Performance status	
0	44
≥1	3
Stage	
II	20
III	6
IV	21
Primary site	
Larynx	18
Oropharynx	11
Nasopharynx	7
Hypopharynx	7
Nasal cavity	2
Oral cavity	2
Histology	
Squamous cell carcinoma	47
Cisplatin dosage[a]	
80	5
100	26
300	11
Docetaxel or nedaplatin	5
Radiation schedule	
Conventional fractionation	41
Hyperfractionation	6

[a]Cumulative doses are shown (mg/m^2).

A retrospective review of patients with head and neck cancers who underwent definitive chemoradiotherapy in our facility was performed along with an investigation of the risk factors for dysphagia induced by chemoradiotherapy.

PATIENTS AND METHODS

From December 1998 to March 2006, 47 patients with head and neck cancers underwent definitive chemoradiotherapy in our facility. The patients' characteristics are shown in Table 1. In our facility, definitive chemoradiotherapy had been usually eligible for the patients whose performance status was good, who had no distant metastasis and who were not so old (≤75 years, basically).

Table 2. Chemotherapy regimens

Chemotherapy agents	Number of patients
Cisplatin (10 mg/m^2 on days 36–40, 43–47) + 5-FU (400 mg/m^2 on days 36–40, 43–47)	26
Cisplatin (50 mg/m^2 on days 6–7, 41–42, 71–72) + 5-FU (800 mg/m^2 on days 1–5, 36–40, 43–47)	9
Cisplatin (80 mg/m^2 on day 29) + 5-FU (400 mg/m^2 on days 29–33)	5
Others	7

All except two patients underwent platinum-based concomitant chemoradiotherapy; the two exceptions were treated by radiotherapy and docetaxel-alone chemotherapy, respectively. Various chemotherapy regimens were adopted in the treatment (Table 2). Since we had sought the optimal regimen of chemotherapy for years and had changed the way of the therapy, there had been heterogeneity as to chemotherapeutic agents in the present study. The cumulative dose of *cis*-diamminedichloroplatinum (cisplatin) ranged from 80 to 300 mg/m^2 (median, 100 mg/m^2). 5-Fluorouracil (5-FU) was administered to 43 patients. The cumulative dose of 5-FU ranged from 2000 to 12 000 mg/m^2 (median, 4000 mg/m^2).

In radiation therapy, casts for immobilization and a photon beam of 4 MV were used in all patients. The fraction size was 1.5–2.0 Gy. The total dose of radiation therapy ranged from 50 to 70 Gy, and median dose was 70 Gy. Since various treatment protocols with different fraction sizes and total doses had been used in our facility, we also calculated a biologic effective dose (BED) in a linear-quadratic model (5). BED was defined as $nd(1 + d/\alpha/\beta)$, with units of Gy, where n is the fractionation number, d the daily dose and α/β was assumed to be 10 for tumors. The BED ranged from 60 to 84 Gy (median, 84 Gy). Forty-one patients were treated by a once-daily fractionation schedule and six patients were treated by an accelerated hyperfractionation schedule. In this schedule, patients initially received 40 Gy in once-daily fractionation with a fraction size of 2 Gy. After that, radiation fields were shrinked down to avoid the spinal cord and 30 Gy was added in twice-daily fractionation with a fraction size of 1.5 Gy. Lateral opposing portals alone or lateral opposing and anterior portals (three-field approach) were used according to the individual tumor spread. Stage II disease was usually treated by locally confined portals. The whole neck was included in the treatment of Stages III–IV disease initially. Spinal cord was usually avoided by cone-down field reduction after the administration of 40 Gy. Computed tomography images for radiation dose distribution were attained in 14 patients. None of the patients underwent intensity-modulated radiation therapy (IMRT). Overall treatment time ranged from 31 to 109 days (median, 50 days).

Toxicity was assessed using the Common Terminology Criteria for Adverse Events version 3.0 (National Cancer

Institute, Rockville, MD, USA). In these criteria, Grade 3 dysphagia is defined as symptomatic and severely altered eating and/or swallowing, which requires intravenous fluids, tube, feeding or total parenteral nutrition for more than 24 h. To evaluate radiation portal size, the length of the side of the equivalent square in each lateral opposing field was calculated; the median length was 11.3 cm (5.5–16.5 cm).

Statistical analyses were performed using Fisher's exact test for univariate analysis and the logistic regression model was used for multivariate analysis. Statistical significance for all analyses was set at $P < 0.05$. Survival rates were calculated from the start of treatment. Survival curves were calculated using the Kaplan–Meier method. These analyses were performed using the statistical software JMP version 5.1.1 (SAS Institute Inc., Cary, NC, USA).

RESULTS

Median follow-up time was 21 months (range, 3–85 months). Severe (Grade ≥3) dysphagia was observed in 22 patients (47%) as an acute toxic event. Severe (Grade ≥3) dermatitis occurred in 18 patients and severe (Grade ≥3) mucositis was observed in 18 patients.

In univariate analysis, the relationships between severe dysphagia and the following parameters were examined: age (<70 vs. ≥70 years old), performance status according to the Eastern Cooperative Oncology Group (0 vs. ≥1), pre-treatment body weight loss (<10% vs. ≥10%), smoking (<20 vs. ≥20 cigarettes per day), primary site (oro-hypopharynx vs. others), clinical stage (II vs. III–IV), radiation portal size (length of the side of the equivalent square <11 vs. ≥11 cm), cumulative dose of cisplatin (<100 vs. ≥100 mg/m^2), cumulative dose of 5-FU (<4000 vs. ≥4000 mg/m^2) and radiation schedule (conventional fractionation vs. hyperfractionation). The results of univariate analysis are shown in Table 3. Primary site, clinical stage and radiation portal size were found to significantly influence the rate of severe dysphagia. Four parameters were chosen for multivariate analysis: primary site, clinical stage, radiation portal size and cumulative dose of cisplatin. The results of multivariate analysis are shown in Table 4. In this analysis, only radiation portal size was found to have a significant effect on the outcome ($P = 0.048$).

Among the 22 patients who developed severe dysphagia, opioid analgesics were administered to 13 patients and antibiotics were administered to 14 patients. As a measure for the management of severe dysphagia, total parenteral nutrition was usually adopted in our facility. Percutaneous endoscopic gastrostomy and nasogastric tubes were not usually placed. Seventeen patients required total parenteral nutrition. The median duration of severe dysphagia was 53 days (range, 21–142 days). Those patients also required prolonged hospitalization after termination of the treatment (15–117 days; median, 42). Ten patients presented some sort of dysphagia at the last follow-up. One patient had been dependent on tube feeding for more than a year.

Table 3. Univariate analysis to identify risk factors for severe dysphagia

Variable	Rate of patients with severe dysphagia	*P* value
Age (years)		
<70	43% (13/30)	
≥70	53% (9/17)	0.56
Performance status		
0	48% (21/44)	
≥1	33% (1/3)	1.00
Pre-treatment weight loss (%)		
<10	44% (16/36)	
≥10	55% (6/11)	0.73
Smoking (CPD)		
<20	48% (12/25)	
≥20	45% (10/22)	1.00
Primary site		
Oro-hypopharynx	67% (12/18)	
Others	34% (10/29)	0.041
Clinical stage		
II	25% (5/20)	
III–IV	63% (17/27)	0.017
Radiation portal size[a] (cm)		
<11	18% (4/22)	
≥11	72% (18/25)	<0.001
Cumulative dose of cisplatin (mg/m^2)		
<100	39% (14/36)	
≥100	73% (8/11)	0.083
Cumulative dose of 5-FU (mg/m^2)		
<4000	44% (4/9)	
≥4000	47% (18/38)	1.00
Radiation schedule		
Conventional fractionation	47% (20/43)	
Hyperfractionation	50% (2/4)	1.00

CPD, cigarettes per day.
[a]Length of the side of the equivalent square in each lateral opposing field was used as a surrogate for radiation portal size.

DISCUSSION

Cisplatin-based chemoradiotherapy for locally advanced head and neck cancers is now recognized as a standard

Table 4. Multivariate analysis to identify risk factors for severe dysphagia

Variable	Odds ratio (95% confidence interval)	*P* value
Clinical stage		
II		
III–IV	1.41 (0.23–7.48)	0.69
Primary site		
Oro-hypopharynx	1.84 (0.32–10.78)	0.49
Others		
Radiation portal size[a] (cm)		
<11		
≥11	6.03 (1.08–42.06)	0.048
Cumulative dose of cisplatin (mg/m^2)		
<100		
≥100	1.99 (0.29–15.80)	0.49

[a]Length of the side of the equivalent square in each lateral opposing field was used as a surrogate for radiation portal size.

therapy for patients with inoperable disease because of its larger survival benefit than radiation therapy alone (3). Sometimes, this non-surgical therapy can be adopted in operable patients to achieve better cosmetic outcome and organ preservation. There is still room for improvement of this therapy. Efforts to determine the optimal dosage of cytotoxic agents and optimal timing of chemotherapy and radiotherapy are still underway (6). Despite using a non-surgical modality, this can be a rather toxic form of therapy (7). Dysphagia caused by the therapy sometimes becomes severe and may last for a long time. This complication is thought to be one of the largest obstacles in conducting concomitant chemoradiotherapy for head and neck cancers. Few previous studies have addressed this issue (8), but some reports mentioned that more than half of the cases required enteral feeding temporarily (9) and approximately 20% required long-term enteral feeding (4). Rademaker et al. (10) reported that it took approximately 1 year for a patient whose eating ability was impaired by the therapy to recover to close to the normal level. Nguyen et al. (11,12) reported that aspiration was frequently observed during the course of therapy, sometimes leading to fatal aspiration pneumonia.

As mentioned above, it is becoming clear that concomitant chemoradiotherapy for head and neck cancers can be quite severe for patients. Therefore, care should be taken in judging whether a patient really requires concomitant chemotherapy (13). Administration of cisplatin at a dose of 100 mg/m^2 is the standard therapy, but only two-thirds of the patients can receive all cycles of treatment with such a regimen (14). Improving compliance is one of the most pressing problems remaining to be resolved. Logeman et al. (15) reported that alteration of chemotherapy protocols had minimal effect on swallowing function, which may mean that arrangement of usual cytotoxic agents would not reduce the severity of this complication. Recently, the use of biologically targeted therapy has been shown to improve the outcome without increasing the common toxic effects (16). These newly emerging approaches represent promising means of improving treatment outcome in these patients.

Few studies have addressed risk factors for severe dysphagia in chemoradiotherapy for head and neck cancers. Mangar et al. (9) argued that clinical stage, general condition and history of smoking could be the risk factors for severe dysphagia. In the present study, smoking was not found to be significant. This was assumed to be due to the strict prohibition against smoking by patients during the course of therapy in the present study. Regarding general condition, this type of therapy is usually confined to patients with good performance status and this may cause selection bias. Machtay et al. (17) reported that older age was a strong risk factor for severe late toxicity. In the present study, which was aimed at early toxicity, older age was not identified as an independent risk factor. Almost all patients aged 70 or over had excellent performance status in the present study. The adaptation of this therapy is rather selective in our facility, which may result in suppression of the risk of dysphagia in aged patients. Radiation portal size was found to be a risk factor for severe dysphagia in chemoradiotherapy for head and neck cancers in the present study. Clinical stage was also associated with severe dysphagia in univariate analysis, which was similar to the previous report by Mangar et al., but not in multivariate analysis. This could be explained by a requirement of larger radiation portals for higher clinical stage, so there should be confounding factors between them. The results presented here suggest that radiotherapy plays a major role in the occurrence of dysphagia. It is supposed that broader mucous membranes and more anatomical parts important for swallowing would be affected to a greater degree by larger radiation portals, and these must be amplified by chemotherapy. Some reports suggested that primary site of disease could be an important risk factor (15,17). We also identified that primary site was associated with severe dysphagia in univariate analysis, but not in multivariate analysis. These observations may also indicate the importance of radiotherapy in the occurrence of dysphagia, as higher radiation dose is usually administered to the primary site of disease.

Accordingly, improving radiotherapy might lead to relief of this complication. IMRT has been widely used for head and neck cancers (18). Using this advanced technique, complications can be reduced without compromising therapeutic outcome. Good local control has been achieved in a number of leading institutions. Xerostomia, which arises as an late toxic event, is less severe than with conventional radiotherapy (18,19). Chemo-IMRT may cause dysphagia to some extent, but it may be less severe than chemotherapy and altered fractionation schedule (20), and requires less long-term tube feeding (21). The further development of newly

emerging approaches such as IMRT may result in a decrease in the severity of dysphagia.

Dysphagia is a complication for which clinicians should be prepared. It is important to take appropriate measures for this complication. Rosenthal et al. (4) reported the importance of rehabilitation as a means of coping with dysphagia. It would be useful to identify patients at high risk of severe dysphagia in advance so that clinicians could pay attention to this complication from the early stages of therapy.

CONCLUSIONS

Larger radiation portal size could be a risk factor for severe dysphagia after chemoradiotherapy for head and neck cancers. Patients treated with broad radiation portals should be managed carefully during the course of therapy.

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Conflict of interest statement

None declared.

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CLINICAL INVESTIGATION **Radiation Oncology Practice**

JAPANESE STRUCTURE SURVEY OF RADIATION ONCOLOGY IN 2005 BASED ON INSTITUTIONAL STRATIFICATION OF PATTERNS OF CARE STUDY

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Purpose: To evaluate the structure of radiation oncology in Japan in terms of equipment, personnel, patient load, and geographic distribution to identify and improve any deficiencies.

Methods and Materials: A questionnaire-based national structure survey was conducted between March 2006 and February 2007 by the Japanese Society of Therapeutic Radiology and Oncology. These data were analyzed in terms of the institutional stratification of the Patterns of Care Study.

Results: The total numbers of new cancer patients and total cancer patients (new and repeat) treated with radiotherapy in 2005 were estimated at approximately 162,000 and 198,000, respectively. In actual use were 765 linear accelerators, 11 telecobalt machines, 48 GammaKnife machines, 64 ^{60}Co remote-controlled after-loading systems, and 119 ^{192}Ir remote-controlled after-loading systems. The linear accelerator systems used dual-energy function in 498 systems (65%), three-dimensional conformal radiotherapy in 462 (60%), and intensity-modulated radiotherapy in 170 (22%). There were 426 Japanese Society of Therapeutic Radiology and Oncology-certified radiation oncologists, 774 full-time equivalent radiation oncologists, 117 medical physicists, and 1,635 radiation therapists. Geographically, a significant variation was found in the use of radiotherapy, from 0.9 to 2.1 patients/1,000 population. The annual patient load/FTE radiation oncologist was 247, exceeding the Blue Book guidelines level. Patterns of Care Study stratification can clearly discriminate the maturity of structures according to their academic nature and caseload.

Conclusions: The Japanese structure has clearly improved during the past 15 years in terms of equipment and its use, although the shortage of manpower and variations in maturity disclosed by this Patterns of Care Study stratification remain problematic. These constitute the targets for nationwide improvement in quality assurance and quality control. © **2008 Elsevier Inc.**

Structure survey, Radiotherapy facility, Radiotherapy personnel, Radiotherapy equipment, Caseload.

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INTRODUCTION

The medical care systems of the United States and Japan have very different backgrounds. In 1990, the Patterns of Care Study (PCS) conducted a survey of the 1989 structure of radiation oncology facilities for the entire census of facilities in the United States. The results of the survey, together with trends in the structure of specialization since 1974, were reported in detail by Owen *et al.* (1). In 1991, the Japanese Society of Therapeutic Radiation Oncology (JASTRO) conducted the first national survey of the structure of radiotherapy (RT) facilities in Japan based on their status in 1990, with the results reported by Tsunemoto (2). The first comparison of these two national structure surveys to illustrate the similarities and differences present in 1989–1990 was conducted by Teshima *et al.* (3) and reported in 1995. The resultant international exchange of information proved valuable for both countries, because each could improve their own structure of radiation oncology using those data.

The Japanese structure of radiation oncology has improved in terms of the greater number of cancer patients who are treated with RT, as well as the public awareness of the importance of RT, although problems still exist that should be solved. The JASTRO has conducted national structure surveys every 2 years since 1990 (4). In Japan, an anticancer law was enacted in 2006 in response to patients' urgent petitions to the government. This law strongly advocates the promotion of RT and increasing the number of radiation oncologists (ROs) and medical physicists. The findings of the international comparisons and the consecutive structural data gathered and published by the JASTRO have been useful in convincing the Japanese bureaucracy of the importance of RT. In this report, the recent structure of radiation oncology in Japan is presented, with reference to data obtained from previous international comparisons.

METHODS AND MATERIALS

Between March 2006 and February 2007, the JASTRO conducted a questionnaire using a national structure survey of radiation oncology in 2005. The questionnaire included the number of treatment machines by type, number of personnel by category, and number of patients by type, site, and treatment modality. For variables measured over a period, data were requested for the calendar year 2005. The response rate was 712 (96.9%) of 735 of active facilities. The data from 511 institutions (69.5%) were registered in the International Directory of Radiotherapy Centres in Vienna, Austria in April 2007.

The PCS was introduced in Japan in 1996 (5–11). The PCS in the United States used structural stratification to analyze the national averages for the data in each survey item using two-stage cluster sampling. The Japanese PCS used similar methods. We stratified the RT facilities nationwide into four categories for the regular structure surveys. This stratification was based on academic conditions and the annual number of patients treated with RT in each institution, because the academic institutions require, and have access to, more resources for education and training and the annual caseload also constitutes essential information related to structure. For the present study, the following institutional stratification was used: A1, university hospitals/cancer centers treating ≥440 patients/y; A2, the same type of institutions treating ≤439 patients/y; B1, other national/public hospitals treating ≥130 patients/y; and B2, other national hospital/public hospitals treating ≤129 patients/y.

The Statistical Analysis Systems, version 8.02 (SAS Institute, Cary, NC), software program (12) was used for statistical analyses, and statistical significance was tested using the chi-square test, Student *t* test, or analysis of variance.

RESULTS

Current situation of radiation oncology in Japan

Table 1 shows that the numbers of new patients and total patients (new plus repeat) requiring RT in 2005 were estimated at approximately 162,000 and 198,000, respectively. According to the PCS stratification of institutions, almost 40% of the patients were treated at academic institutions (categories A1 and A2), even though these academic institutions constituted only 18% of the 732 RT facilities nationwide.

The cancer incidence in Japan in 2005 was estimated at 660,578 (13) with approximately 25% of all newly diagnosed patients treated with RT. The number has increased steadily during the past 10 years and is predicted to increase further (4).

Facility and equipment patterns

Table 2 lists the RT equipment and related function. In actual use were 767 linear accelerators, 11 telecobalt machines, 48 Gamma Knife machines, 65 ^{60}Co remote-controlled afterloading systems (RALSs), and 119 ^{192}Ir RALSs. The linear accelerator system used dual-energy function in 498 systems

Table 1. PCS stratification of radiotherapy facilities in Japan

Institution Category	Description	Facilities (*n*)	New patients (*n*)	Average new patients/facility* (*n*)	Total patients (new + repeat) (*n*)	Average total patients/facility* (*n*)
A1	UH and CC (≥440 patients/y)	66	45,866	694.9	54,885	831.6
A2	UH and CC (<440 patients/y)	67	17,161	256.1	21,415	319.6
B1	Other (≥130 patients/y)	290	71,627	247.0	88,757	306.1
B2	Other (<130 patients/y)	289	21,664	75.0	26,116	90.4
Total		712	156,318†	219.5	191,173†	268.5

Abbreviations: PCS = Patterns of Care Study; UH = university hospital; CC = cancer center hospital; Other = other national, city, or public hospital.

* $p < 0.0001$.

† Number of radiotherapy institutions was 735 in 2005, and number of new patients was estimated at approximately 162,000; corresponding number of total patients (new plus repeat) was 198, 000.

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

RT equipment and function	A1 (n = 66)		A2 (n = 67)		B1 (n = 290)		B2 (n = 289)			Total (n = 712)	
	n	%	n	%	n	%	n	%	p	n	%
Linear accelerator	133		85		283		264		—	765	
With dual energy function	97	72.9*	62	72.9*	197	69.6*	142	53.8*	<0.0001	498	65.1*
With 3D-CRT function (MLC width ≤1.0 cm)	109	82.0*	59	69.4*	176	62.2*	118	44.7*	<0.0001	462	60.4*
With IMRT function	65	48.9*	25	29.4*	55	19.4*	25	9.5*	<0.0001	170	22.2*
Annual patients/linear accelerator	412.7†		243.8†		279.9†		93.4†		<0.0001	234.6†	
Particle	5		0		1		1		—	7	
Tomotherapy	0		0		0		1		—	1	
Microtron	8		3		9		4		—	24	
Telecobalt (actual use)	7 (5)		6 (1)		7 (1)		14 (4)		—	34 (11)	
Gamma Knife	6		3		32		7		0.0004	48	
^{60}Co RALS (actual use)	8 (8)	12.1‡ (12.1)	13 (12)	19.4‡ (17.9)	41 (36)	14.1‡ (12.4)	12 (8)	4.2‡ (2.8)	<0.0001	74 (64)	10.4‡ (9.0)
^{192}Ir RALS (actual use)	53 (52)	80.3‡ (78.8)	27 (24)	38.8‡ (34.3)	35 (35)	12.1‡ (12.1)	8 (8)	2.8‡ (2.8)	<0.0001	123 (119)	17.1‡ (16.6)
^{137}Cs RALS (actual use)	0 (0)		0 (0)		2 (2)		0 (0)		—	2 (2)	

Abbreviations: 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.

* Percentage calculated from number of systems using this function and total number of linear accelerator systems.

† Percentage calculated from number patients and number of institutions with linear accelerators; institutions without linear accelerators excluded from calculation.

‡ Percentage of institutions that have this equipment (≧2 pieces of equipment per institution).

(65%), three-dimensional conformal RT in 462 (60%), and intensity-modulated RT (IMRT) in 170 (22%). These functions were installed more frequently in the equipment of academic institutions than in that of nonacademic institutions ($p < 0.0001$). The annual numbers of patients/linear accelerator were 413 for A1, 244 for A2, 280 for B1, and 93 for B2 institutions. The number of institutions with telecobalt machines in actual use showed a major decrease to 11. The Gamma-Knife machine was installed more frequently in B1 institutions. A significant replacement of ^{60}Co RALS by ^{192}Ir RALS was observed, especially in academic institutions. We had seven particle machines, three with carbon beam and five with proton beam RT. The total number of patients treated at the seven institutions was estimated at approximately 1,600 (1% of all new patients in Japan). Eleven advanced institutions were included in the A1 category and treated >800 patients annually. They were equipped with linear accelerators with dual-energy function (71% of the institutions), three-dimensional conformal RT function (89%) and IMRT function (70%), as well as with ^{192}Ir-RALS (90%) and a computed tomography (CT) simulator (100%).

Table 3 lists the RT planning and other equipment. X-ray simulators were installed in 70% of all institutions, and CT simulators in 55%. A significant difference was found in the rate of CT simulator installation by institutional stratification, from 91% in A1 to 45% in B2 institutions ($p < 0.0001$). Only a very few institutions used magnetic resonance imaging for RT, although computer use for RT recording was pervasive.

Staffing patterns and patient loads

Table 4 lists the staffing patterns and patients loads by institutional stratification. The total number of full-time equivalent (FTE) ROs in Japan was 774. The average number of FTE ROs was 4.41 for A1, 1.43 for A2, 0.89 for B1, and 0.45 for B2 institutions ($p < 0.0001$). The patient load/FTE RO in Japan was 247, and the number for A1, A2, B1, and B2 institutions was 189, 224, 343, and 202, respectively ($p < 0.0001$), with the patient load for B1 institutions by far the greatest. In Japan, 40% of the institutions providing RT had their own designated beds, and ROs must also take care of their inpatients. The percentage of distribution of institutions by patient load/FTE RO is shown in Fig. 1 and indicates that the largest number of facilities featured a patient/FTE staff level of 101–150, with 151–200 the second largest number. More than 60% of the institutions (438 of 712) had <1 FTE RO, as shown by the gray areas of the bars.

A similar trend for radiation technologists and their patient load by stratification of institutions was observed ($p < 0.0001$). The percentage of distribution of institutions by patient load/radiation technologist is also shown in Fig. 2. The largest number of facilities had a patient/RT technologist level in the 81–100 range, with 101–120 the second largest number. There were 117 full-time (and 30 part-time) medical physicists and 257 full-time (and 13 part-time) RT quality assurance staff. In this survey, duplication reporting of these personnel numbers could not be checked because of a lack of

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

RT planning and other equipment	A1 (n = 66)		A2 (n = 67)		B1 (n = 290)		B2 (n = 289)		p	Total (n = 712)	
	n	%	n	%	n	%	n	%		n	%
X-ray stimulator	58	84.8*	53	76.1*	201	68.6*	190	65.7*	0.0130	502	69.7*
CT stimulator	66	90.9*	48	68.7*	163	54.8*	130	44.6*	<0.0001	407	55.3*
RTP computer (≥2)	209 (190)	100* (71.2)	114 (82)	94.0* (46.3)	336 (101)	95.9 (14.8)	281 (50)	88.6* (8.7)	0.0005 (<0.0001)	940 (146)	93.1* (20.5)
MRI (≥2)	164 (153)	95.5* (78.8)	134 (124)	94.0* (79.1)	470 (351)	96.9 (55.9)	344 (148)	92.4* (24.6)	0.1136 (<0.0001)	1,112 (338)	94.7* (47.5)
For RT only	3	3.0*	1	1.5*	5	1.7*	3	0.7*		12	1.4*
Computer use for RT recording	63	95.5*	62	92.5*	263	90.7*	238	82.4*	0.0015	626	87.9*

Abbreviations: CT = computed tomography; RTP = radiotherapy planning; MRI = magnetic resonance imaging; other abbreviations as in Table 2.
* Percentage of institutions that have equipment (≥2 pieces of equipment per institution).

individual identification on staffing data. Finally, there were 907 nurses and clerks.

Distributions of primary sites, specific treatment and palliative treatment

Table 5 lists the distribution of primary sites by institutional stratification. The most common disease site was the breast, followed by lung/bronchus/mediastinum and genitourinary. In Japan, the number of patients with prostate cancer undergoing RT was approximately 13,200 in 2005, but the number has been increasing most rapidly. The stratification of institutions indicated that more patients with lung cancer were treated at the nonacademic institutions (B1 and B2), and more patients with head-and-neck cancer were treated at academic institutions (A1 and A2; $p < 0.0001$).

Table 6 lists the distribution of use of specific treatment and the number of patients treated with these modalities by the PCS stratification of institutions. Brachytherapy, such as intracavitary RT, interstitial RT, and radioactive iodine therapy, for prostate cancer was used more frequently in academic institutions than in nonacademic institutions ($p < 0.0001$). Similar trends were observed for other specific treatments such as total body RT, intraoperative RT, stereotactic brain RT, stereotactic body RT, IMRT, thermoradiotherapy, and RT of the pterygium by ^{90}Sr. In 2005, 4.6% of patients (n = 755) were treated with IMRT at 33 institutions. This percentage was significantly lower than that of institutions using linear accelerators with IMRT function (22%; Table 2).

Table 7 lists the number of patients with any type of brain metastasis or bone metastasis treated with RT according to the same institutional stratification. B1 institutions treated more patients with brain metastasis (11% of all patients) than other types of institutions ($p < 0.0001$), and the use of RT for bone metastasis ranged from 11% for A1 to 19% for B2 ($p < 0.0001$). Overall, more patients were treated with RT at nonacademic type B2 institutions than at A1 or A2 institutions.

Geographic patterns

Figure 3 shows the geographic distributions of the annual number of patients (new plus repeat) per 1,000 population by 47 prefectures arranged in order of increasing number of JASTRO-certified physicians per 1,000,000 population (14). Significant differences were found in the use of RT, from 0.9 patients/1,000 population (Saitama and Okinawa) to 2.1 (Hokkaido). The average number of patients/1,000 population per quarter ranged from 1.37 to 1.57 (p = 0.2796). A tendency was found for a greater number of JASTRO-certified physicians to be accompanied by an increased use of RT for cancer patients, although the correlation was not statistically significant. The use rate of RT in a given prefecture was not necessarily related to its population density in 2005, just as we observed in the 1990 data (3).

DISCUSSION

In 1990, fewer facilities for RT were available and fewer patients were treated with RT in Japan than in the United States. However, the numbers for Japan improved

Table 4. Structure and personnel by PCS institutional stratification

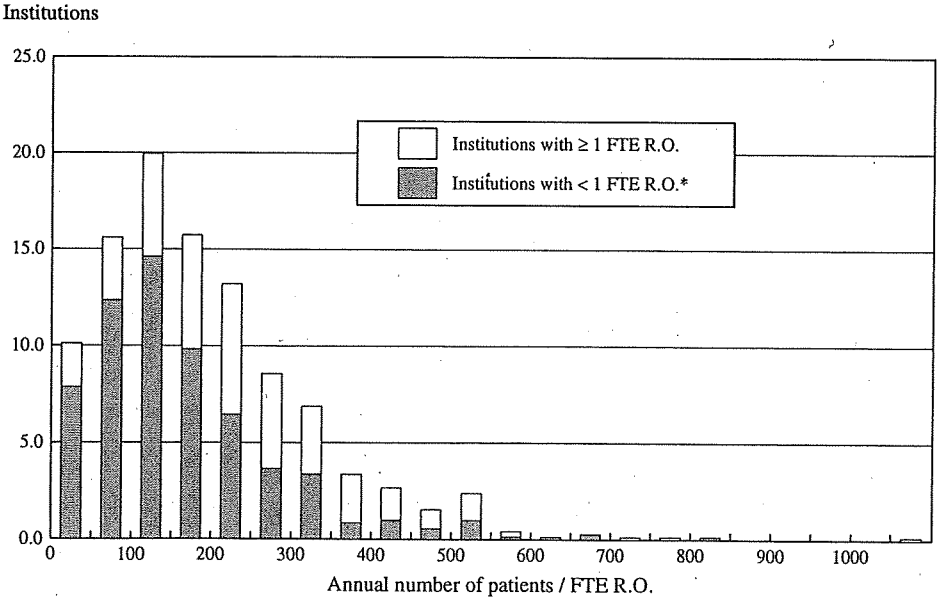
	Structure and personnel					
	A1 (n = 66)	A2 (n = 67)	B1 (n = 290)	B2 (n = 289)	*p-value*	Total (n = 712)
Institutions/total institutions (%)	9.3	9.4	40.7	40.6		100
Institutions with RT bed (n)	57 (86.4)	35 (52.2)	127 (43.8)	68 (23.5)		287 (40.3)
Average RT beds/institution (n)	14.0	4.8	3.4	1.0		3.6
JASTRO-certified RO (full time)	181	62	139	44		426
Average JASTRO-certified RO/institution (n)	2.7	0.9	0.5	0.2	<0.0001	0.6
Total (full-time and part-time) RO FTE*	290.9	95.55	258.77	129.24		774.46
Average FTE ROs/institution	4.41	1.43	0.89	0.45	<0.0001	1.09
Patient load/FTE RO	188.7	224.1	343.0	202.1	<0.0001	246.8
Total RT* technologists	388.6	176.3	637.7	431.9		1634.5
Average technologists/institution (n)	5.9	2.6	2.2	1.5	<0.0001	2.3
Patient load/RT technologist	141.2	121.5	139.2	60.5	<0.0001	117.0
Total nurses/assistants/clerks (n)	202.2	92.4	390.55	221.8		907
Full-time medical physicists + part-time (n)	51 + 10.1	8 + 7	39 + 7	19 + 6		117 + 30.1
Full-time RT QA staff + part-time	81 + 0	31 + 7	102.5 + 3	42.3 + 3		256.8 + 13

Abbreviations: 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.

Data in parentheses are percentages.

significantly during the next 15 years, with respective increases by factors of 2 and 2.6 compared with those in 1990 (3). However, the use rate of RT for new cancer patients remained at 25%, less than one-half the ratio in the United States and European countries. The anticancer law was enacted in Japan to promote RT and education for ROs, as well as medical physicists or other staff members, from April 2006. For the implementation of this law, comparative data of the structure of radiation oncology in Japan and the United States, as well as relevant PCS data, proved helpful. Because the increase in the elderly population of developed countries is the greatest in Japan, RT is expected to play an increasingly important role.

Compared with 1990, the number of linear accelerator systems increased significantly by 2.3 times, and the percentage of systems using telecobalt decreased to 7%. Furthermore, the functions of linear accelerators, such as dual energy, three-dimensional conformal RT (multileaf collimator width <1 cm), and IMRT improved. The number of high-dose-rate RALS in use increased by 1.4 times and the use of



* Number of .FTEs for institutions with FTE<1 was calculated as FTE=1 to avoid overestimating pateint' load/R.O.

Fig. 1. Percentage of institutions by patient load/full-time equivalent (FTE) staff of radiation oncologists (RO) in Japan. White bars represent institutions with one or more FTE staff, and gray bars represent institutions with fewer than one FTE radiation oncologist. Each bar represents interval of 50 patients/FTE radiation oncologist.

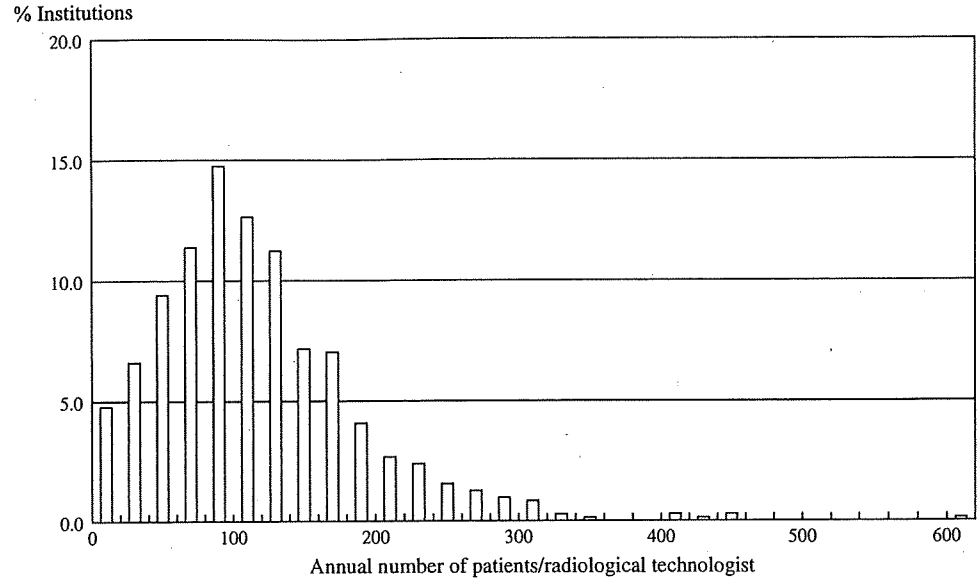


Fig. 2. Percentage of institutions by patient load/radiotherapy technologist in Japan. Each bar represents interval of 20 patients/full-time equivalent staff.

^{60}Co-RALS has largely been replaced by ^{192}Ir-RALS. CT simulators were installed in 55% of institutions nationwide, and RT planning systems were used in 93%, for an increase in the number of RT planning systems of 4.87 times. The maturity of the functions of linear accelerator and greater possession rates of CT simulators and systems using ^{192}Ir-RALS were closely related to the institutional stratification by PCS, which could therefore aid in the accurate discrimination of structural maturity and immaturity and the identification of structural targets to be improved. The Japanese PCS group published structural guidelines based on the PCS data (16), and we plan to use this structural data for a new PCS to revise the Japanese structural guidelines.

The staffing patterns in Japan also improved in terms of numbers. However, the institutions that had fewer than one FTE RO on their staff still accounted for >60% nationwide, and this rate did not change during the 15 years from 1990 to 2005. In Japan, most institutions still rely on part-time ROs. First, the number of cancer patients who require RT is increasing more rapidly than the number of ROs. Second, specialist fees for ROs in academic institutions are not recognized by the Japanese medical care insurance system, which is strictly controlled by the government. Most ROs must therefore work part-time at affiliated hospitals in the B1 and B2 groups to earn a living. Thus, to reduce the number of institutions that rely on part-time ROs and might encounter

Table 5. Primary sites of cancer treatment with RT in 2005 by PCS institutional stratification for new patients

	A1 (n = 65)		A2 (n = 67)		B1 (n = 285)		B2 (n = 284)		Total (n = 701)	
Primary site	n	%	n	%	n	%	n	%	n	%
Cerebrospinal	2,603	5.6	770	4.5	4,431	6.4	795	3.6	8,599	5.6
Head and neck (including thyroid)	6,318	13.7	2,372	13.9	6,033	8.7	1,650	7.5	16,373	10.6
Esophagus	3,164	6.9	1,171	6.9	4,426	6.4	1,452	6.6	10,213	6.6
Lung, trachea, and mediastinum	7,069	15.3	2,639	15.5	14,946	21.5	5,386	24.6	30,040	19.4
Lung	5,469	11.8	2,272	13.3	12,917	18.6	4,734	21.6	25,392	16.4
Breast	8,945	19.4	3,049	17.9	14,148	20.4	4,119	18.8	30,261	19.6
Liver, biliary tract, pancreas	1,936	4.2	713	4.2	2,742	3.9	964	4.4	6,355	4.1
Gastric, small intestine, colorectal	1,897	4.1	806	4.7	3,742	5.4	1,399	6.4	7,844	5.1
Gynecologic	3,253	7.0	1,156	6.8	3,405	4.9	855	3.9	8,669	5.6
Urogenital	5,544	12.0	2,043	12.0	8,068	11.6	2,905	13.3	18,560	12.0
Prostate	4,290	9.3	1,385	8.1	5,627	8.1	1,916	8.8	13,218	8.6
Hematopoietic and lymphatic	2,460	5.3	1,052	6.2	3,624	5.2	904	4.1	8,040	5.2
Skin, bone, and soft tissue	1,607	3.5	749	4.4	1,830	2.6	1,018	4.6	5,204	3.4
Other (malignant)	705	1.5	235	1.4	822	1.2	313	1.4	2,075	1.3
Benign tumors	664	1.4	268	1.6	1,289	1.9	135	0.6	2,356	1.5
Pediatric <15 y (included in totals above)	435	0.9	123	0.7	187	0.3	302	1.4	1,047	0.7
Total	46,165	100	17,023	100	69,506	100	21,895	100	154,589†	(100)

Abbreviations as in Table 2.
*Number of total number of new patients different with these data, because no data on primary sites were reported by some institutions.

Table 6. Distribution of specific treatments and numbers of patients treated with these modalities by PCS stratification of institutions

	A1 (n = 66)		A2 (n = 67)		B1 (n = 290)		B2 (n = 289)			Total (n = 712)	
Specific therapy	n	%	n	%	n	%	n	%	p	n	%
Intracavitary RT (n)									<0.0001		
Treatment facilities	61	92.4	37	55.2	71	24.5	12	4.2		181	25.4
Cases	1,670		527		974		75			3,246	
Interstitial RT									<0.0001		
Treatment facilities	42	63.6	14	20.9	18	6.2	5	1.7		79	11.1
Cases	1,818		286		638		31			2,773	
Radioactive iodine therapy for prostate cancer									<0.0001		
Treatment facilities	25	37.9	6	9.0	7	2.4	1	0.3		39	5.5
Cases	1,166		152		430		17			1,765	
Total body RT									<0.0001		
Treatment facilities	60	90.9	36	53.7	78	26.9	17	5.9		191	26.8
Cases	706		237		687		108			1,738	
Intraoperative RT									<0.0001		
Treatment facilities	23	34.8	12	17.9	20	7.0	11	3.8		66	9.3
Cases	212		39		111		25			387	
Stereotactic brain RT									<0.0001		
Treatment facilities	46	69.7	31	46.3	91	31.4	29	10.0		197	27.7
Cases	1,680		482		8,513		447			11,122	
Stereotactic body RT									<0.0001		
Treatment facilities	31	50.0	14	20.9	36	12.4	11	3.8		92	12.9
Cases	482		263		679		234			1,658	
IMRT									<0.0001		
Treatment facilities	16	24.2	4	6.0	12	4.1	1	0.3		33	4.6
Cases	426		67		212		50			755	
Thermoradiotherapy									0.0004		
Treatment facilities	10	15.2	4	6.0	15	5.2	7	2.4		36	5.1
Cases	339		27		134		81			581	

Abbreviations: PCS = Patterns of Care Study; RT = radiotherapy; IMRT = intensity-modulated radiotherapy.

problems with their quality of care, a drastic reform of our current medical care systems is required. However, great care is needed to ensure that the long-term success of radiation oncology in Japan and patient benefits are well balanced with the costs. Even under the current conditions, however, the number of FTE ROs increased by 2.1 times compared with the number in 1990 (3). However, the patient load/FTE RO also increased by 1.4 times to 247 during the same period, perhaps reflecting the growing popularity of RT because of recent advances in technology and improvement in clinical results. This caseload ratio in Japan has already exceeded the limit of the Blue Book guidelines of 200 patients/RO (15, 16). The percentage of distribution of institutions by patient load/RO showed a slightly smaller distribution than that of the United States in 1989 (3). Therefore, Japanese radiation oncology seems to be catching up quickly with the western system despite limited resources. Furthermore, additional recruiting and education of ROs are now top priorities of the JASTRO.

The distribution of patient load/RT technologists showed that 13% of institutions met the narrow guideline range (100–120/RT technologist), and the rest were densely distributed around the peak. Compared with the distribution in the United States in 1989, >20% of institutions in Japan had a relatively low caseload of 10–60 because a large number of smaller B2-type institutions still accounted for nearly 40% of institutions exceeding the range of the guidelines. As for medical physicists, a similar analysis for patient load/FTE staff was difficult, because the number was still small, and they were working mainly in metropolitan areas. In Japan, radiation technologists have been acting as medical physicists, so that their education has been changed from 3 to 4 years

Table 7. Brain metastasis or bone metastasis patients treated with RT in 2005 by PCS institutional stratification

	Patients					
Metastasis	A1 (n = 66)	A2 (n = 67)	B1 (n = 290)	B2 (n = 289)	p	Total (n = 712)
Brain	2,565 (4.7)	1,204 (5.6)	9,774 (11.0)	1,778 (6.8)	<0.0001	15,321 (8.0)
Bone	6,243 (11.4)	2,845 (13.3)	13,331 (15.0)	5,057 (19.4)	<0.0001	27,476 (14.4)

Data presented as number of patients, with percentages in parentheses.

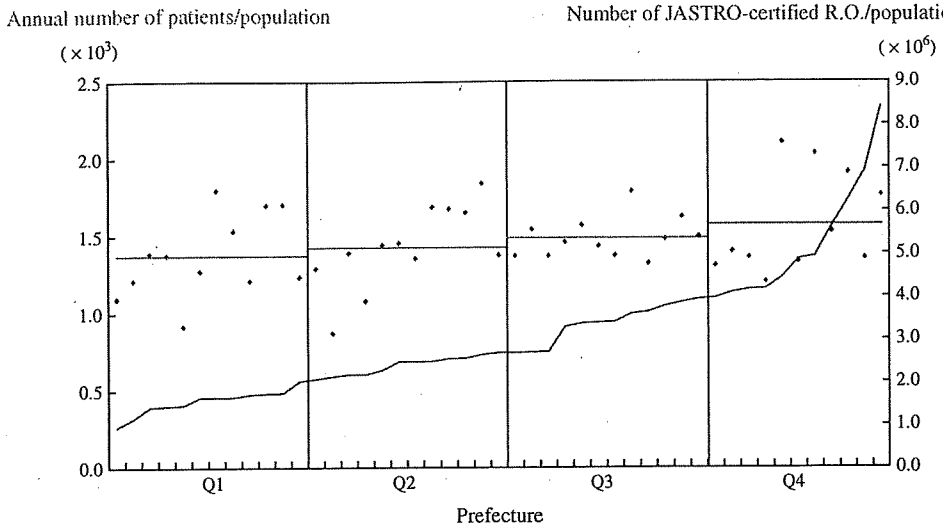


Fig. 3. Geographic distribution for 47 prefectures of annual number of patients (new plus repeat) per 1,000 population arranged in order of increasing number of Japanese Society of Therapeutic Radiation Oncology (JASTRO)-certified radiation oncologists (RO)/1,000,000 population by prefecture. Q1, 0–25%; Q2, 26–50%; Q3, 51–75%; and Q4, 76–100%. Horizontal bar shows average annual number of patients (new plus repeat) per 1,000 population of prefectures per quarter.

during the past decade and graduate and postgraduate courses have been introduced. Currently, those who have obtained a master's degree or radiation technologists with enough clinical experience can take the examination for qualification as a medical physicist, as can those with a master's degree in science or engineering, like those in the United States or Europe. In Japan, a unique education system for medical physicists might be developed because the anticancer law actively supports improvements in quality assurance/quality control specialization for RT. However, the validity of this education and training system remains unsatisfactory, because we are still in the trial-and-error stage.

The distribution of the primary site for RT showed that more lung cancer patients were treated in B1 or B2 nonacademic institutions and more head-and-neck cancer patients were treated in A1 or A2 academic institutions. These findings might be because more curative patients were referred to academic institutions and more palliative patients with lung cancer were treated in nonacademic institution in Japan. In addition, more patients with bone metastasis were treated in nonacademic institutions. The use of specific treatments and the number of patients treated with these modalities were significantly affected by institutional stratification, with more specific treatments performed at academic institutions. These findings indicate that significant differences in the patterns of care, as reflected in the structure, process, and, possibly, outcomes for cancer patients still exist in Japan. These differences point to opportunities for improvement. We, therefore, based the Japanese Blue Book guidelines on this stratification by the PCS data (16) and are now in preparing to revise them accordingly.

The geographic patterns demonstrated significant differences among the prefectures in the use of RT, ranging from 0.9 to 2.1 patients/1,000 population. Furthermore, the number of JASTRO-certified physicians/population might be associated with the use of RT, so that a shortage of ROs or medical physicists on a regional basis will remain a major concern in Japan. The JASTRO has been making every effort to recruit and educate ROs and medical physicists through public relations, training courses, involvement in the national examination for physicians, and seeking to increase the reimbursement by the government-controlled insurance program, and other actions.

CONCLUSION

The Japanese structure of radiation oncology has clearly improved during the past 15 years in terms of equipment and its functions, although a shortage of manpower and differences in maturity by type of institution and caseload remain. Structural immaturity is an immediate target for improvement, and, for improvements in process and outcome, the PCS or National Cancer Database, which are currently operational and being closely examined, can be expected to play an important role in the future.

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