factors for patients who underwent pulmonary metastasectomy. Furthermore, we identified the surgical indications for pulmonary metastasis from head and neck squamous cell carcinomas.

Patients and Methods

The Metastatic Lung Tumor Study Group of Japan developed a database for registration of lung metastasis cases of patients undergoing surgical resection. It documents the following: sex, age, primary tumor histopathology, stage of the primary tumor, treatment for the primary tumor, date of primary surgery, type of surgery, curability, date of metastasis, disease-free interval (DFI), side, size, number of resected metastases, date of metastasectomy, relapsed sites, and follow-up. The DFI was calculated from the date of the initial treatment for the primary cancer to the date of diagnosis of pulmonary metastasis. Between March 1984 and September 2006, 237 patients who underwent resection of pulmonary metastases from head and neck cancers were enrolled in the database. The endpoint of our retrospective study was survival after pulmonary metastasectomy. The Ethics Committees of the affiliated institutions approved this database study and waived the need for informed consent from patients as long as patient data remained anonymous.

Of the 237 patients with pulmonary metastases, 98 patients had nonsquamous cell carcinoma. Because nonsquamous cell carcinomas have various histological types and better survival, cases with lung metastasis from nonsquamous cell carcinoma were excluded from analysis [6, 10]. In addition, because pulmonary metastases from oral cavity cancers are reported to have a poor prognosis [8], special emphasis was placed on investigating the differences between oral cavity and non–oral cavity cancers. Twenty-five cases were excluded because of incomplete data, including the number of resected metastases, age, DFI, or prognosis. A central review of the pathologic specimens was not carried out by our study group. The data from the remaining 114 patients were retrospectively reviewed. Preoperative examination, surgical indication, operative procedure, and postoperative treatment were at the discretion of the institution where the patient was treated. The surgical procedure depended on the location, size, or number of metastases. Lymph node dissection was not routinely performed and depended on the institution. As previously reported [12], general indications for surgical resection of pulmonary metastasis followed the criteria of Thomford and coworkers [13]: the primary lesion was under control or was planned to be under control; there were no metastases to other organs; and the patient's general condition was good enough to withstand surgery.

Statistical Analysis

Overall survival was analyzed by the Kaplan-Meier method, and differences in variables were calculated by the log-rank test. The date of pulmonary resection was defined as the starting point. The Cox proportional hazards regression analysis was used for multivariable analysis. The data were calculated using version 5.0 of the StatView software package (SAS Institute, Cary, NC). Values of p less than 0.05 were considered statistically significant.

Table 1. Characteristics of Patients Undergoing Surgery for Pulmonary Metastases From Head and Neck Squamous Cell Carcinomas

Characteristic	Number (%)
Male	93 (82)
Female	21 (18)
Location of primary site	
Larynx	32 (28)
Oral cavity	27 (24)
Hypopharynx	24 (21)
Nasal cavity and paranasal sinuses	9 (8)
Mesopharynx	7 (6)
Salivary gland	4 (4)
Epipharynx	3 (3)
Other sites	8 (7)
Treatment for the primary tumor	
Surgery and radiotherapy	40 (35)
Surgery	30 (27)
Surgery and chemoradiotherapy	26 (23)
Surgery and chemotherapy	7 (6)
Radiotherapy	5 (4)
Chemoradiotherapy	4 (4)
Unknown	2 (2)
Surgical procedure	
Lobectomy	62 (54)
Wedge resection	37 (33)
Segmentectomy	10 (9)
Pneumonectomy	5 (4)
Lymph node dissection	
Positive	55 (48)
Negative	40 (35)
Unknown	19 (17)

Results

Patient characteristics and the primary site locations of head and neck squamous cell carcinomas are listed in Table 1. The TNM stages for head and neck primary cancers were not recorded in detail. The patients' mean age at the time of pulmonary metastasectomy was 63 years (range, 26 to 81). The mean tumor size was 3.3 cm (range, 0.7 to 11 cm). The median number of resected metastatic lesions per patient was 1 lesion (range, 1 to 6). The median DFI was 16 months (range, 0 to 87). The median follow-up time from the time of metastasectomy was 120 months.

One patient died of pneumonia during the perioperative period. The operative mortality rate was 0.9%. The overall 5-year survival rate after pulmonary metastasectomy was 26.5% (Fig 1). The median survival time was 26 months. Survival according to each primary site is shown in Table 2. The patients with oral cavity cancer showed

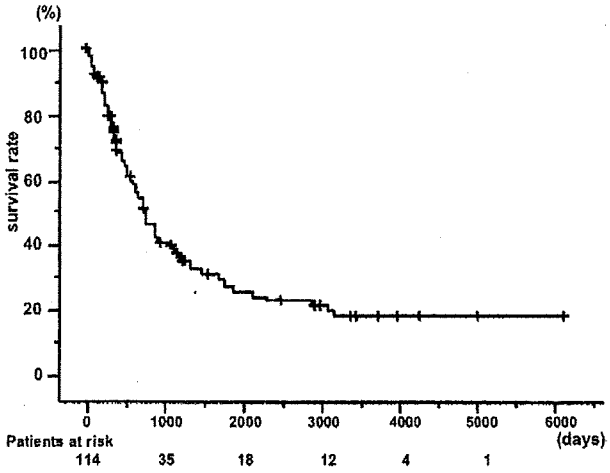

Fig 1. Overall survival of 114 patients after pulmonary metastasectomy for head and neck squamous cell carcinoma. The 5-year survival rate was 26.5%.

significantly worse prognosis than the other cancer patients ($p = 0.03$). Postoperative therapy after pulmonary metastasectomy was as follows: chemotherapy in 17 patients, chemoradiotherapy in 6 patients, and radiation in 5 patients. There was no significant difference between the no adjuvant therapy group and the adjuvant groups. We assessed the relationship between survival and the following clinical factors: sex, age (≥ 75 or < 75 years), tumor size (> 3 or ≤ 3 cm), number of resected metastases (solitary or multiple), resected side (unilateral or bilateral), location of primary sites (oral cavity or non-oral cavity), primary lymph node metastasis, DFI (> 24 or ≤ 24 months), and curability (complete or incomplete). Table 3 shows the results of univariate analyses of survival and clinical factors. Oral cavity cancers, lymph node metastasis, DFI 24 months or less, and incomplete resection are poor prognostic factors. Table 4 shows the results of multivariate analyses of survival and clinical factors. Male sex, oral cavity cancers, lymph node metastasis, and incomplete resection were poor prognostic factors.

Because being male and having oral cavity cancers could be considered preoperative prognostic factors, the patients were divided into two groups for further analysis: males with oral cavity cancers (n = 17), and others (n = 97). Survival of the male patients with metastatic oral cavity cancer was significantly worse ($p < 0.001$; Fig 2). No male patients with metastatic oral cavity cancer remained alive 5 years after undergoing pulmonary metastasectomy.

Table 2. Five-Year Survival of Patients With Pulmonary Metastasis According to Primary Site

Primary Site	Number	5-Year Survival (%)
Larynx	32	40.9
Oral cavity	27	9.2
Hypopharynx	24	19.8
Nasal cavity and paranasal sinuses	9	47.6
Mesopharynx	7	28.6
Salivary gland	4	33.3
Epipharynx	3	0
Other sites	8	42.9

Table 3. Survival of 114 Patients According to Clinical Variables of Pulmonary Metastases

Variables	n (%)	5-Year Survival (%)	p Value
Male	93 (82)	22.9	0.355
Female	21 (18)	41.3	
Age, years			
≥75	17 (15)	43.7	0.234
<75	97 (85)	24.4	
Size			
≤ 3 cm	70 (61)	31.8	0.820
> 3 cm	44 (39)	23.3	
Number			
Solitary	84 (74)	26.0	0.646
Multiple	30 (26)	27.3	
Resected side			
Unilateral	104 (91)	25.8	0.240
Bilateral	10 (9)	34.3	
Primary site			
Non-oral cavity	87 (76)	32.4	< 0.001
Oral cavity	27 (24)	9.2	
Lymph node metastasis			
Positive	30 (26)	13.8	0.010
Negative	84 (74)	32.0	
Disease-free interval			
> 24 months	31 (27)	40.0	0.044
≤ 24 months	83 (73)	21.0	
Curability			
Complete	102 (89)	26.7	0.037
Incomplete	12 (11)	25.0	

Table 4. Relationship of Individual Variables to Outcome, Cox's Proportional Hazards Regression Analysis

Variable	Risk Ratio	95% CI	p Value
Male	2.93	1.41–6.09	0.004
Age, < 75 years	0.99	0.44–2.23	0.986
Size > 3 cm	0.91	0.55–1.51	0.715
Multiple lung metastasis	1.70	0.97–3.00	0.066
Bilateral lung metastasis	0.49	0.14–1.65	0.248
Oral cavity origin	3.67	1.99–6.76	< 0.001
Lymph node metastasis	2.09	1.20–3.61	0.009
Disease-free interval ≤ 24 months	1.70	0.94–3.07	0.081
Incomplete resection	2.47	1.25–4.87	0.009

CI = confidence interval.

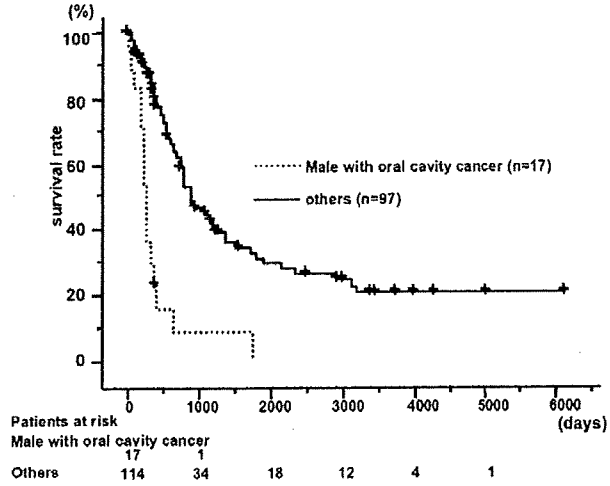

Fig 2. Survival curves based on two groups, males with oral cavity cancer (dotted line [n = 17]) and others (solid line [n = 97]), obtained by dividing by prognostic factors.

Comment

This study revealed a 5-year survival rate after pulmonary metastases from head and neck squamous cell carcinoma of 26.5%, and showed that male sex, oral cavity cancer, lymph node metastasis, and curability are prognostic factors. Nibu and colleagues [8] investigated 32 patients with squamous cell carcinoma of the head and neck who underwent thoracotomy for pulmonary metastases, and reported an overall 5-year survival rate of 32%. Finley and coworkers [9] reported a 29% 5-year survival rate for 18 patients who underwent complete resection of pulmonary metastases from head and neck squamous cell carcinomas, and showed that the survival of patients who underwent metastasectomy was significantly better than that of patients who did not. Wedman and colleagues [6] investigated 138 patients with pulmonary metastases from head and neck cancers, and reported that the 5-year survival rate for 21 patients who underwent pulmonary metastasectomy was 59%, compared with 4% in the nonmetastasectomy group.

Compared with other treatments, we believe that the role of pulmonary resection for metastasis from head and neck squamous cell carcinomas has been established. However, previous studies have been small and of limited sample size. We analyzed data from a large number of patients enrolled in a multi-institutional registry and assessed prognostic factors for pulmonary metastasectomy by multivariate analysis. With regard to prognostic factors after pulmonary metastasectomy that were determined by other investigators, oral cavity cancers, mediastinal lymph node metastasis, and pleural invasion were all negative factors [8]. As determined by multivariate analysis, incomplete resection, complications associated with surgery, and adjuvant therapy of the primary tumor were unfavorable prognostic factors [14]. Liu and associates [15] reported 83 cases of pulmonary metastasis from head and neck cancers, and demonstrated that incomplete resection, age less than 50 years, and DFI of 2 years or less were poor prognostic factors. Disease-free interval is commonly recognized as a significant prognostic factor in various types of pulmonary metastasis [4]. In other reports, DFI longer than 12 months and solitary lung metastasis were favorable prognostic factors for metastatic head and neck cancers [9, 10]. However, the multivariate analysis of this study determined that DFI was not significantly associated with surgical outcome. Disease-free interval depends on the follow-up period or accuracy of diagnostic procedure. Although a short DFI might reflect aggressive and invasive biological behavior, the evaluation of DFI remains difficult as a prognostic factor.

In accordance with a report by Nibu and colleagues [8], our analysis demonstrated that metastatic oral cavity cancer was a significantly worse prognostic factor. On the other hand, Leon and associates [16] showed that the primary site of head and neck cancers is a significant prognostic factor for distant metastasis, and that cancer in the oral cavity had the lowest risk for distant metastasis. Distant metastases originating from oral cavity cancer depend on disease stage [17]. In our multi-institutional study, we could not determine in detail the stage of primary cancer, and oral cavity cancer patients with pulmonary metastasis might have included many advanced stage cases. We investigated the basis behind why metastasized oral cavity cancer has a worse prognosis than other types of head and neck cancer, but unfortunately, could not find the reason. The biological behavior of oral cavity cancers might be different from that of other head and neck cancers. Further study is needed to clarify this issue.

Male sex has been reported to be a prognostic factor in resected pulmonary metastasis from head and neck squamous cell carcinoma [10]. We did not investigate smoking behavior or comorbidities in this study, and that is an important weakness in the study. Smoking status is a well-known unfavorable prognostic factor and might be related to the results of this study with regard to male sex.

Head and neck cancers have varying histology and occur at various primary sites. Some investigators have studied pulmonary metastasis from nonsquamous cell head and neck cancers [6, 10, 15]. The benefits of metastasectomy for nonsquamous cell carcinoma have not been clarified [15]. Because the biological character of nonsquamous cell carcinoma in head and neck cancers is very different from that of squamous cell carcinoma, we focused our study on squamous cell carcinoma. There were 98 nonsquamous cell carcinoma cases registered in our database. The origins of the metastatic cancers were as follows: thyroid 35, salivary gland 34, oral cavity 3, epipharynx 2, mesopharynx 2, and other sites 22. The overall survival of patients with nonsquamous cell carcinomas was significantly better than that of patients with squamous cell carcinoma, and the 5-year survival rate of nonsquamous cell carcinoma patients was 68.4% (data not shown).

In this study, the percentage of lobectomy was relatively high at 54%. We consider the reason for the high rate of lobectomy to be the difficulty in the preoperative diagnosis of pulmonary metastasis from primary lung cancer. In

addition, as the mean tumor size was 3.3 cm, lobectomy was a suitable indication for the large tumor size.

Rush [3] has stated that the most important factors for selecting patients for surgery are control of the primary tumor, ability to resect all metastatic disease, absence of extrathoracic disease, and lack of better alternative systemic therapy. Regarding the surgical indications for pulmonary metastasis from head and neck cancers, Liu and colleagues [15] gave the following criteria: the metastasis is limited to the lungs, the lesions are all resectable, and locoregional control of the head and neck primary cancer is obtained or obtainable. Complete resection and locoregional control of primary sites are obviously essential. Our data also suggest that metastatic oral cavitary cancers, especially in male patients, have a poor prognosis. Therefore, indications for surgery in metastatic head and neck squamous cell carcinomas should include consideration of the types of primary sites.

There are some limitations to our study. First, we should examine each primary site, but the numbers of cancers at each site are quite small. Large-scale databases are needed to clarify each head and neck cancer. Second, a histopathologic differential diagnosis between head and neck squamous cell carcinomas and lung squamous cell carcinomas is often difficult. In general, the patient's clinical course and stage of primary sites were used to help diagnose whether the patient had pulmonary metastasis or primary lung squamous cell carcinoma. Because the present study was a retrospective analysis, and the differential diagnosis was made at the discretion of each institution, our data might include primary lung cancer. A report on a loss of heterozygosity analysis revealed that 18 of 44 cases of squamous cell lung lesions, which had been clinically interpreted as metastases from head and neck cancers, were considered to be second primary lung cancers [18]. Additional advances in molecular techniques and analysis are needed to further elucidate this complicated problem. Third, there is a selection bias affecting pulmonary metastasectomy outcome results. Most of the reports of the results of metastasectomy come from thoracic surgery centers [6], and candidates for pulmonary metastasectomy are strictly selected based on the aforementioned criteria. Therefore, the present study may be presenting relatively good survival rates. However, selection bias is unavoidable and is a difficult problem to resolve. A prospective randomized trial for pulmonary metastasis treatment is ethically difficult, and is not practical.

In conclusion, we identified prognostic factors for pulmonary metastases from head and neck squamous cell carcinomas. According to multivariate analyses, male sex, oral cavity cancer, lymph node metastasis, and incomplete resection are poor prognostic factors. Male patients with pulmonary metastasis from oral cavity cancers have a poor prognosis, and pulmonary metastasectomy for these patients may not be beneficial. Since there are adequate selection criteria for patients, a good outcome after surgery is promising, with careful preoperative examination, including positron emission tomography [17, 19], and selection.

References

1. Shingaki S, Suzuki I, Kobayashi T, Nakajima T. Predicting factors for distant metastases in head and neck carcinomas: an analysis of 103 patients with locoregional control. J Oral Maxillofac Surg 1996;54:853–7.
2. Ferlito A, Shaha AR, Silver CE, Rinaldo A, Mondin V. Incidence and sites of distant metastases from head and neck cancer. ORL J Otorhinolaryngol Relat Spec 2001;63: 202–7.
3. Rusch VW. Pulmonary metastasectomy. Current indications. Chest 1995;107:322–31.
4. Pastorino U, Buyse M, Friedel G, et al. Long-term results of lung metastasectomy: prognostic analyses bases on 5206 cases. J Thorac Cardiovasc Surg 1997;113:37–49.
5. Davidson RS, Nwogu CE, Brentjens MJ, Anderson TM. The surgical management of pulmonary metastasis: current concepts. Surg Oncol 2001;10:35–42.
6. Wedman J, Balm AJ, Hart AA, et al. Value of resection of pulmonary metastases in head and neck cancer patients. Head Neck 1996;18:311–6.
7. Yamagata K, Onizawa K, Otsuka Y, Yoshida H. Treatment for lung metastasis from head and neck squamous cell carcinoma: a preliminary study of docetaxel. Oral Maxillofac Surg 2008;12:13–8.
8. Nibu K, Nakagawa K, Kamata S, et al. Surgical treatment for pulmonary metastases of squamous cell carcinoma of the head and neck. Am J Otolaryngol 1997;18:391–5.
9. Finley RK, Verazin GT, Driscoll DL, et al. Results of surgical resection of pulmonary metastases of squamous cell carcinoma of the head and neck. Am J Surg 1992;164:594–8.
10. Chen F, Sonobe M, Sato K, et al. Pulmonary resection for metastatic head and neck cancer. World J Surg 2008;32:1657–62.
11. Ueda Y, Fujii Y, Udagawa H. Thoracic and cardiovascular surgery in Japan during 2006. Gen Thorac Cardiovasc Surg 2008;56:365–88.
12. Kawamura M, Nakajima J, Matsuguma H, et al. Surgical outcomes for pulmonary metastases from hepatocellular carcinoma. Eur J Cardiothorac Surg 2008;34:196–9.
13. Thomford NR, Woolner LB, Clagett OT. The surgical treatment of metastatic tumors in the lungs. J Thorac Cardiovasc Surg 1965;49:357–63.
14. Winter H, Meimarakis G, Hoffmann G, et al. Dose surgical resection of pulmonary metastases of head and neck cancer improve survival? Ann Surg Oncol 2008;15:2915–26.
15. Liu D, Labow DM, Dang N, et al. Pulmonary metastasectomy for head and neck cancers. Ann Surg Oncol 1999;6: 572–8.
16. Leon X, Quer M, Orus C, del Prado Venegas M, Lopez M. Distant metastases in head and neck cancer patients who achieved loco-regional control. Head Neck 2000;22:680–6.
17. Betka J. Distant metastases from lip and oral cavity cancer. ORL J Otorhinolaryngol Relat Spec 2001;63:217–21.
18. Geurts TW, Nederlof PM, van den Brekel MW, et al. Pulmonary squamous cell carcinoma following head and neck squamous cell carcinoma: metastasis or second primary? Clin Cancer Res 2005;11:6608–14.
19. Wong RJ. Current status of FDG-PET for head and neck cancer. J Surg Oncol 2008;97:649–52.

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Cine MRI enables better therapeutic planning than CT in cases of possible lung cancer chest wall invasion

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ABSTRACT

The objective: To evaluate the hypothesis that lung cancer treatment planning (whether or not to use induction therapy) can be improved if respiratory dynamic cine magnetic resonance imaging (RD MR) is used.
Method: We studied 100 lung cancer patients, 76 men and 21 women, scheduled for thoracotomies between May 1997 and December 2006 wherein it was unclear preoperatively whether chest wall invasion would be found. We evaluated the accuracy of RD MR as compared with the findings at operation and postoperative pathology. The accuracy of RD MRI for evaluating chest wall invasion was compared with the efficacy of CT and MRI within our own group of patients and with data from the studies of other investigators.
Results: Concerning the evaluation of chest wall invasion, conventional computed tomography (CT) had 43.9% specificity, 60.0% sensitivity and 47.1% accuracy, while RD MR had 68.5% specificity, 100.0% sensitivity and 77.0% accuracy. RD MRI was particularly useful in the evaluation of cancers around 5 cm in diameter that were located adjacent to the diaphragm. Postoperative evaluation of superior sulcus tumor cases that had received induction therapy also showed that the RD MR procedure enabled an accurate decision in 87.5% of cases, and there were no false negative cases.
Conclusions: RD MR is more useful than CT or standard MRI for evaluating thoracic wall invasion. This noninvasive method enhances the reliability of deciding whether induction therapy should be employed.

1. Introduction

Since accurate evaluation of chest wall invasion by lung cancer is essential for precise staging and therapeutic strategy planning, there have been several studies using computed tomography (CT) or magnetic resonance (MRI) [1–7].

The recently developed high-speed respiratory dynamic MRI (RD MR) has the potential to provide accurate information on chest wall invasion and contribute to deciding on lung cancer staging, which might avoid the need to change surgical strategy intraoperatively, with attendant prolongation of operation time [8,9]. This is of particular importance when deciding on the indications of induction chemoradiotherapy in cases of superior sulcus tumor (SST) [10].

Simple contact of tumor and adjacent chest wall does not necessarily mean invasion, and even CT or conventional MR findings can be ambiguous concerning thoracic invasion.

On breathing, the chest wall and lungs move independently of each other. However, when a tumor invades only as far as the pulmonary pleura, it moves along the chest wall synchronously with breathing, while chest wall movement is limited when tumor invades the chest wall.

We therefore performed a prospective study to determine whether respiratory dynamic cine MRI (RD MR) could provide accurate and reliable information concerning pleural or chest wall invasion in lung cancer.

Abbreviations: CT, computed tomography; ED CT, expiratory dynamic computer tomography; Ef, therapeutic effect; FDG-PET, 18F-fluorodeoxyglucose-positron emission tomography; MRI, magnetic resonance image; NPV, negative predictive value; PPV, positive predictive value; RD MR, respiratory dynamic cine MRI; SST, superior sulcus tumor; SUV, standard uptake value; US, ultrasound.

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2. Materials and methods

In order to evaluate the usefulness of RD MR, we set out to evaluate information on all of the first 100 patients meeting the inclusion criteria and examined by this method, immediately after the equipment was introduced in May 1997 completing the study in December 2006. We enrolled only those in whom it was unclear whether there was invasion to the chest wall, in cases of peripheral lung cancer found to be abutting the pleural surface on a previous conventional static CT scan or MRI.

All cases in which rib destruction or infiltration into the soft tissues of the chest wall was identified by a CT scan or MR imaging were excluded from this study, because chest wall invasion was already clearly demonstrated by those findings. It was assumed that chest wall invasion had already taken place. We felt that once a decision on the status of the chest wall involvement had been made, it would be unethical to expose patients to the greater dose of radiation involved in RD MR. Another 43 patients were excluded because they did not undergo surgery due to distant metastasis or poor respiratory function. The method was developed by the second author of this paper, Dr. Akata. The first 100 patients meeting all our enrolment criteria (non-small cell carcinoma of the lung, suspected to have chest wall invasion, and ultimately operated cases with pathologically verifiable results) and giving written informed consent consisted of 76 men and 24 women, ranging in age from 30 to 84 years (mean 63.0). There were 42 adenocarcinomas, 40 squamous cell carcinomas, 14 large cell carcinomas, 2 adenosquamous cell carcinomas and 2 unclassified adenocarcinomas. The pathological stage of disease was IA in 9 cases, IB in 36 cases, IIA in 1 case, IIB in 20 cases, IIIA in 19 cases, IIIB in 10 cases and IV in 5 cases. Of the 100 cases, 13 were pathological T1, 56 pT2, 24 pT3 and 7 pT4. Almost half, 43 cases, were P0, 17 in P1, 13 in P2, 27 in P3. Tumors were located in the right upper lobe in 35, the right lower lobe in 27, the left upper lobe in 20, the left lower lobe in 17 and one was a multiple primary lung cancer case. Tumors ranged in size from 1.0 to 13.0 (mean 4.93) cm in diameter and only 22 cases were 3 cm in diameter or less. The tumor diameter was larger than 3 cm in 78 cases.

We used 1.5 T MR equipment (MAGNEX 150; Shimadzu Medical Systems, Kyoto, Japan) since 1997. RD MR was acquired with a body coil or spine coil by fast gradient echo sequence (TR = 8 ms, TE = 3 ms, FA = 10°). This sequence has a rewind gradient in phase direction after the completion of readout to maintain a steady state of magnetization. The slice thickness was 10 mm, the matrix was 128 × 128, the number of acquisitions was 2, and 25 consecutive images of the same slice, perpendicular to the abutting point on the chest wall, were taken while the patients breathed deeply.

After 2004, RD MR images were acquired using real-time true fast imaging with steady state precession (True-FISP) cine (Magnetom Symphony; Siemens Medical Systems, Erlangen, Germany), employing a body coil or spine coil with a real-time True-FISP cine sequence (TR = 2.24 ms, TE = 1.12 ms, FA = 74°). This sequence has a rewinding gradient in the phase direction after completion of readout, to maintain the status state of magnetization. The slice thickness was 8 mm, the matrix was 192 × 192 (80%), the number of acquisitions was 1, and 80 consecutive images, same slice obtained from perpendicular to the abutting point on the chest wall, while patients breathed deeply. The image time for 1 slide was 0.3 s and one loop was taken in 24 s. We also used CT scans (ProSeed SA, Yokogawa Medical, Tokyo, Japan) at 1 cm intervals with section thicknesses of 1 cm throughout the entire chest (120 kV, 200 mA, 0.8 s, HP 1.0). Intravenous contrast material iopamidol (Iopamiron 300; Nihon Schering, Osaka, Japan) was used in all cases. Several RD MR loops were taken, changing both the position and direction of the slides at least 3 times depending on the extent of the contact with the chest wall. Patients rehearsed breathing before the examinations which were performed within 3 weeks before surgery. Subjects took few deep breaths slowly for 30 s. MRI sagittal section and tangential projection scans were obtained without employing contrast medium.

The results of RD MR were analyzed to evaluate tumor movement relative to the chest wall, by 3 experienced radiologists blinded to the CT results who reached their conclusions by means of consensus. Chest wall invasion was considered absent if the tumor moved along the chest wall in synchrony with breathing (Fig. 1a). However, when tumor movement was restricted by the chest wall, chest wall invasion was considered present (Fig. 1b).

Lung tumor movement of more than half the height of a vertebra or of the width of a rib was considered to be substantial. Results of all RD MR examinations were analyzed before surgery and then

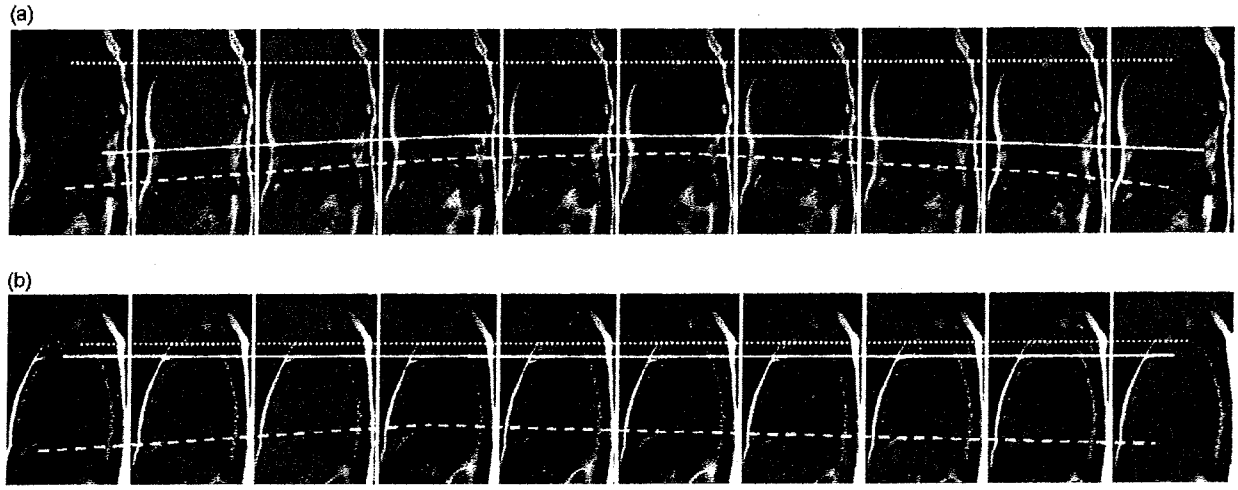

Fig. 1. The tumor on RD MR. (a) On RD MR, the tumor moves along the chest wall in synchrony with breathing. The dashed line connects the top of the diaphragm on 10 consecutive images. During deep breathing, it moves up and down. The unbroken straight line connects the tumor on the 10 consecutive images. During deep breathing, it goes up and down in (a). The dotted line connecting the apex of the lung shows that, during deep breathing, it does not move. Chest wall invasion was ruled out and the absence of invasion to the parietal pleura or chest wall was confirmed during operation. (b) On RD MR, no tumor movement along the chest wall is recognized during respiration. The lines connecting the 10 consecutive images are as described in (a). The unbroken straight line connecting the tumor on the 10 consecutive images shows that it did not move during deep breathing. Invasion was therefore considered likely. On thoracotomy, the adjacent parietal pleura and chest wall were resected in continuity with the primary lesion, and tumor invasion to the chest wall was shown pathologically.

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Table 1
Histopathological findings of chest wall invasion and pathologic Ef according to the General Rules for Clinical and Pathological Records of Lung Cancer of the Japan Lung Cancer Society.

Histopathological findings
p0: Cancer did not extend beyond the elastic membrane of the visceral pleura
p1: Cancer reached the elastic membrane of the visceral pleura
p2: Cancer present on the surface of the visceral pleura
p3: Cancer invaded the chest wall or mediastinum
Pathologic therapeutic effect (Ef) Ef 0: No effect
Ef 1a: Extremely mild effect
Ef 1b: Mild effect
Ef 2: Moderate effect
Ef 3: Complete response

the results were compared with the interoperative findings and the results of gross and microscopic pathologic examination of the resected specimens.

Histopathologic findings were described based on the World Health Organization classification for cell types [12]. Pathological stages were determined based on the TNM classification of the International Union Against Cancer (UICC) [13].

Pathological therapeutic effects were recorded according to the General Rules for Clinical and Pathological Records of Lung Cancer of the Japan Lung Cancer Society to evaluate the response to treatment in solid tumors (Table 1) [14].

All patients provided their written consent to the procedures which were all performed as part of the regular preoperative workup (and since all data are retrospective) and no patient's identity is revealed. Our Institutional Review Board approved data collection and analyses.

3. Results

In 50 of 100 patients, the RD MR showed that the tumor moved along the chest wall in synchrony with breathing (Fig. 2a: case 1). These cases were considered not to have invaded or at most only to the visceral pleura, but not into the chest wall, which was subsequently confirmed during surgery in all cases.

The other 50 patients all appeared to have chest wall invasion on RD MR, because tumor movement was restricted by the chest wall (Fig. 2b: case 2), suggesting possible invasion. However, this was corroborated by pathological examination in only 27/50 cases. In the remaining 23/50 lesions, no invasion was found pathologically, despite the suspicion of invasion on RD MR findings.

Thus, in the 50 cases that appeared to have no chest wall invasion on RD MR, absence of invasion was corroborated on pathological examination (Table 3). Another 23 appearing to have invasion, on RD MR were found not to have invasion pathologically. Of these, 8 (34.8%) were SSTs. The other 27 appearing to have invasion on RD MR were proved to have invasion on resected specimens. No case in which RD MR suggested the absence of invasion i.e. the tumor moved in synchrony with breathing, was found to have invasion or non-malignant fibrous adhesion pathologically.

Pathological examination of all cases showing false-positive RD MR findings of thoracic invasion revealed the cause to be non-malignant fibrous adhesion between the tumor and chest wall in all such cases. Even when tumor and chest wall appeared to form a mass on the RD MR image (Fig. 2c: case 3), the carcinoma sometimes did not invade the chest wall.

In this study, 31 of 100 patients underwent combined resection of the lung and surrounding structures, including resection of the parietal pleura in 9 and the chest wall in 16, and other organs in 6, including vessels, diaphragm, and vertebral bodies.

Induction therapy was performed in 20 stage IIIA cases. Among these, there were 7 SST cases in which concurrent chemoradiotherapy was performed. Pathologically evaluated therapeutic effect (Ef) after induction therapy is shown in Table 2.

Table 2
Effectiveness of chemotherapy.

	After chemotherapy	After concurrent chemoradiotherapy
Ef 0	23.00%	0%
Ef 1a	7.7%	14.3%
Ef 1b	30.80%	14.30%
Ef 2	30.80%	57.10%
Ef 3	7.70%	14.30%

Table 3
The results of specificity, sensitivity, accuracy, positive predictive value (PPV) and negative predictive value (NPV) by conventional static CT and RD MR on the basis of pathological findings.

	Comparison between CT and pathological diagnosis	Comparison between RD MR and pathological diagnosis
Specificity	43.90%	68.50%
Sensitivity	60.0%	100%
Accuracy	47.10%	77.00%
PPV	20.70%	54.00%
NPV	81.80%	100%

The diagnoses based on RD MR and pathologic findings of the surgical specimen are compared in Table 3. For cases of chest wall invasion, the sensitivity and negative predictive value of RD MR were both 100%.

The results shown in Fig. 3 were obtained by the results from the characteristics (histopathology, localization, pathological T-factor, the maximal tumor dimension) of each resected lung specimen according to the results of RD MR.

The factors most related to accurate evaluation on RD MR were appropriate tumor size and suitable location to evaluate tumor movement.

4. Discussion

We set out to determine whether RD MR is a reliable and effective method for detecting the presence of chest wall invasion in cases of peripheral type non-small cell lung cancer. This information is extremely important since it can determine the necessity and type of preoperative treatment and the operative strategy, and, if accurate, can obviate the need for intraoperative change in surgical strategy. We believe that this important information is imperative to decide on the indications of induction chemoradiotherapy when we suspect SST. Rusch et al. [10] reported that in cases of SST, it is essential for cases with invasion to the chest wall to receive induction chemoradiotherapy to extend survival. Therefore one of the purposes of the present study was to determine whether invasion to the chest wall by SST could be accurately determined by RD MR, which is generally considered more accurate than static MR for this purpose [11].

We found that sufficient size and location of the tumor were important factors in deciding on whether the tumor invades surrounding tissue (chest wall, mediastinal pleura, diaphragm, vertebral body) or not. Invasion to surrounding structures can generally be determined in solitary tumors around 5 cm in maximum dimension. Perhaps, the accuracy is lower for tumors larger than 10 cm, because the weight of large tumors limits their mobility even if they are not invading the chest wall. Tumor invasion to the chest wall in the apical area (particularly on the left side) is hard to judge, even by RD MR, because the anatomical architecture tends to limit tumor movement.

Since tumors near the diaphragm are easily affected by respiratory movement, it is relatively simple to evaluate invasion to surrounding structures.

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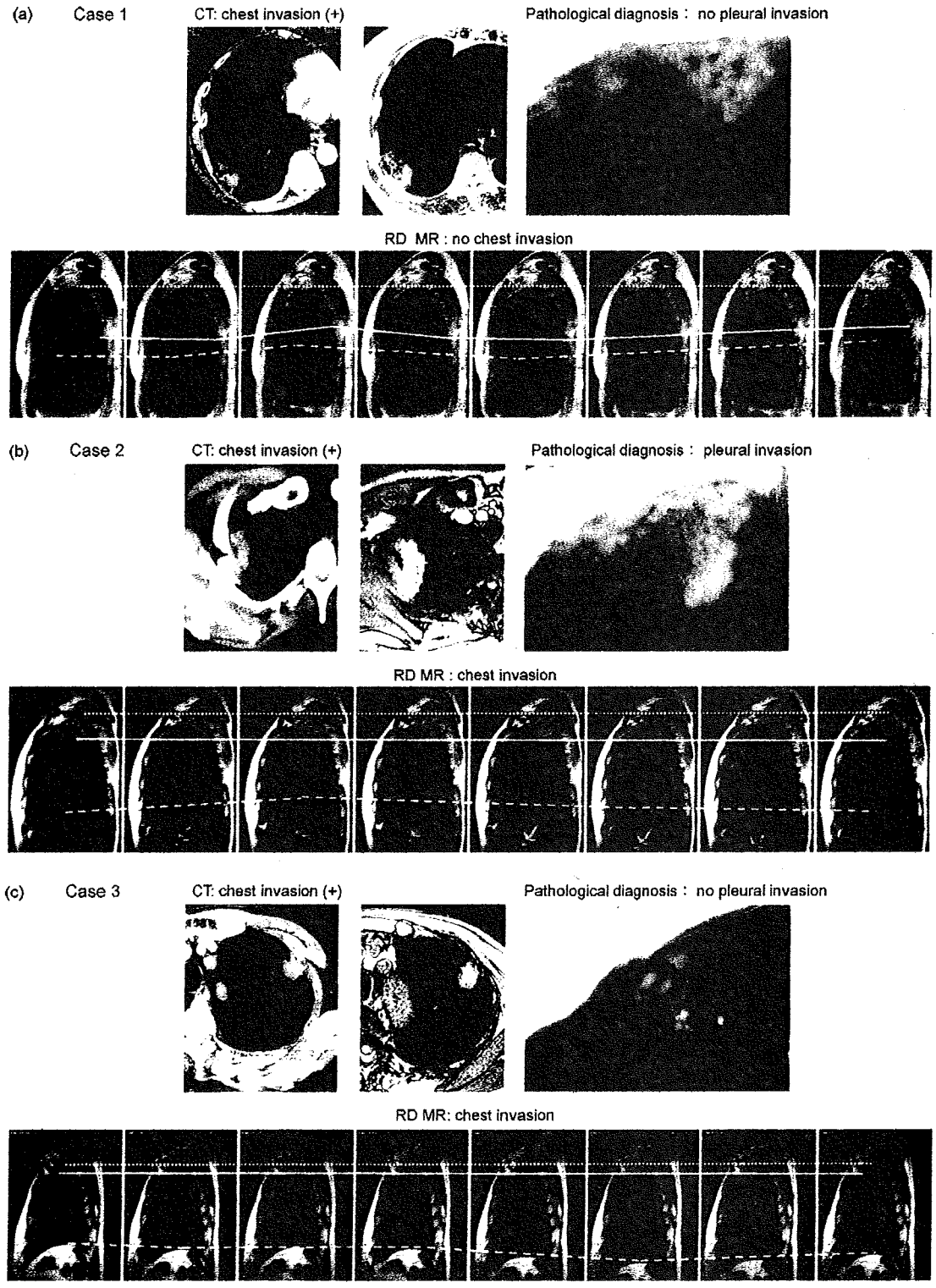

Fig. 2. Comparison between CT and MRI and pathological findings. (a) Case 1: A 79-year-old woman with adenocarcinoma in the right lower lobe. On RD MR, the tumor moves along the chest wall in synchrony with respiration. Chest wall invasion was ruled out and no invasion into the parietal pleura or chest wall was confirmed during operation, and after operation the pathological stage was pT1N0M0 stage IA. In the sectioned surface, the border is indistinct with white and an elliptic form. (b) Case 2: A 40-year-old woman with large cell carcinoma in the right upper lobe. On RD MR, lack of tumor movement along the chest wall during respiration was considered to indicate invasion by the surgeons. The adjacent parietal pleura and chest wall are resected in continuity with the primary lesion. The pathological stage was pT3N0M0 stage IIB. In the sectioned surface, tumor invasion to the chest wall was found histologically (p3). (c) Case 3: A 73-year-old man with adenocarcinoma in the left upper lobe immediately below the pleura. On RD MR, no tumor movement along the chest wall was recognized during respiration. Pathologically, no tumor invasion to the parietal pleura or chest wall was found, but the tumor showed non-malignant adhesion with the parietal pleura. The pathological stage was pT1N0M0 stage IA. In the sectioned surface, the border is indistinct, the tumor appears white and elliptic, and it is accompanied with a cavity. The pleura adhered to the tumor, but no pleural invasion of the tumor was found histologically (p0).

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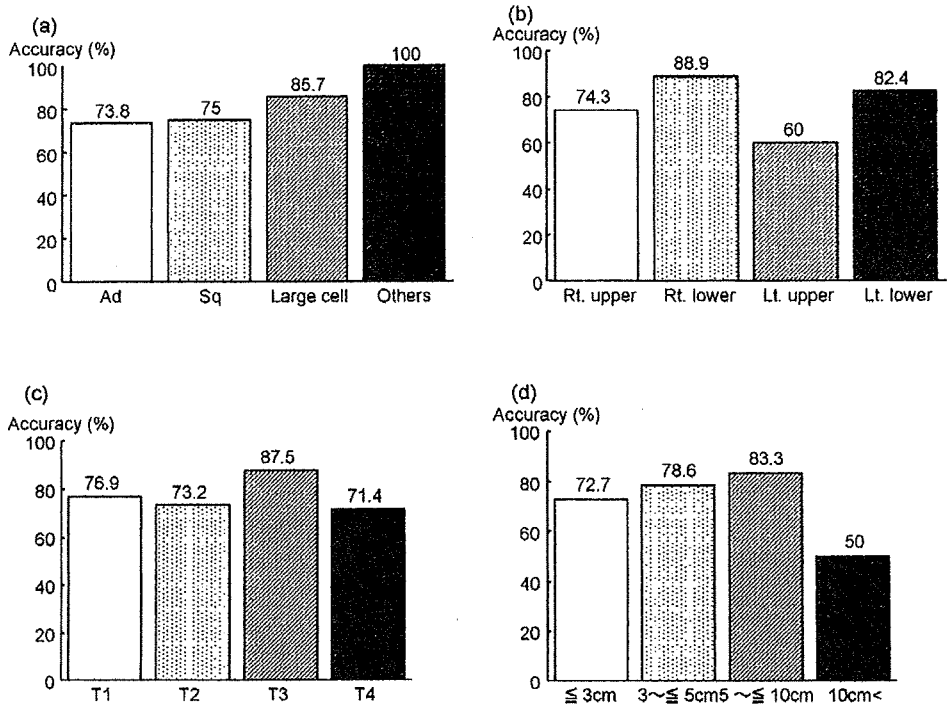

Fig. 3. (a) Accuracy of RD MR in relation to histopathology. (b) Accuracy in relation to tumor's site. (c) Accuracy in relation to T-factor. (d) Accuracy in relation to maximum tumor dimension.

Many studies using conventional CT scan or static MRI have been performed but limitations concerning their ability to detect chest wall invasion have been reported [7,15–18]. The report of Glazer et al. [1], which proposed the effectiveness of the combination of 2 or 3 CT criteria, suggested a method that, although quite sensitive, is not very specific.

Therefore in Table 3, we compared the results of pathological diagnosis and CT examinations by the criteria of Glazer and the results of RD MR. Our prospective study, based on confirmation by examination of resected specimens, showed that RD MR had better results than conventional static CT, using the evaluation method of Glazer, in terms of specificity, sensitivity and accuracy.

Shiotani et al. [19] reported that the detection of the presence or absence of minute amounts of pleural fluid between the lung cancer tumor and chest wall is a key criterion for the determination of chest wall invasion, but this method requires an extremely high level of radiological technique and expertise available only in few institutions. Other methods have been suggested, such as multi-section expiratory dynamic computer tomography (ED CT), using ultrafast CT, and this method, when used for the assessment of tumor movement along the chest wall in cine mode yielded an accuracy of 100%, but that report only described 15 cases [20]. The fact that ultrafast CT is available at only a limited number of institutions, plus the high amount of exposure to radiation, are both drawbacks for this method [20].

Dynamic evaluation using ultrasound (US) has also been reported to have a sensitivity and specificity of 100% and 98% [21]. However dynamic evaluation with US has a limited observation range, and the accuracy of the evaluation depends greatly on the skill and experience of the examiner.

Pneumothorax CT was reported to be useful in assessing chest wall invasion of lung cancer in 43 patients with an accuracy rate of 100% for chest wall invasion and 76% for mediastinal invasion [22]. However, this procedure had the drawback of significant complications (pneumothorax) in 4 patients (9%), one of whom (2%) suffered subcutaneous emphysema. In addition, failure to induce artificial pneumothorax was reported in 3 of those cases [22].

RD MR, although a noninvasive and simple technique, which can be performed in addition to the routine MR examination, is not always totally accurate in distinguishing invasion and non-malignant adhesion to the chest by the tumor. However, this limitation is also present in breathing dynamic ultrafast MRI, ED CT, US and pneumothorax CT, and therefore this problem is common to all these procedures [19–22]. In SST, the accuracy of RD MR was 87.5%.

One limitation of this study was the inability in cases of induction chemotherapy to accurately determine to conversion to non-malignant adhesion of malignant tumor invasion.

The following two useful methods can help to distinguish non-malignant adhesion from the invasion of malignant tumor preoperatively after induction chemotherapy. First is the method of imaging using multi-detector CT (MD-CT) in combination with 18F-fluorodeoxyglucose-positron emission tomography (FDG-PET), which allows evaluation of accumulation of FDG with a quantitative standard uptake value (SUV). The combination of the FDG-PET image which images the function and the MD-CT image which images the form provides understanding of each peculiar feature of the findings of each imaging method and interpretation precision improves [23,24].

The second is CT-guided needle biopsy of the area of adhesion. This confirmation method is generally accurate, but there is the possibility of complications [25–27]. If the site is found to consist only of non-malignant adhesion by either of the above methods, induction therapy can be implemented, followed by operation.

One other limitation of RD MR is that MRI is generally contraindicated in patients who have ferromagnetic materials in certain locations (e.g. cerebral aneurysm clips, intraorbital metallic foreign bodies, and pacemakers).

However, it is clear that RD MR is a simple noninvasive examination that can demonstrate restriction of tumor movement along the chest wall during deep breathing. This method improves the

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precision of diagnosis of chest wall invasion in cases of peripheral type lung cancer abutting on the pleura, in comparison with conventional CT or static MR.

Conflict of interest

The authors declare no conflict of interest.

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References

[1] Glazer HS, Duncan-Meyer J, Aronberg DJ, et al. Pleural and chest wall invasion in bronchogenic carcinoma: CT evaluation. Radiology 1985;157:191–4.
[2] Shirakawa T, Fukuda K, Miyamoto Y, et al. Peripheral pleural invasion of lung masses: evaluation with CT performed during deep inspiration and expiration. Radiology 1994;192:809–11.
[3] Padovani B, Mouroux J, Seksik L, et al. Chest wall invasion by bronchogenic carcinoma: evaluation with MR imaging. Radiology 1994;187:33–8.
[4] Musset D, Grenier P, Carette MF, et al. Primary lung cancer staging: prospective comparative study of MR imaging with CT. Radiology 1986;160:607–11.
[5] Haggar AM, Pearlberg JL, Froelich JW, et al. Chest-wall invasion by carcinoma of the lung: detection by MR imaging. AJR 1987;148:1075–8.
[6] Webb WR, Jensen BG, Sollitto R, et al. Bronchogenic carcinoma: staging with MR compared with staging with CT and surgery. Radiology 1985;156: 117–24.
[7] Grenier P, Dubary B, Carette MF, et al. Preoperative thoracic staging of lung cancer: CT and MR evaluation. Diagn Intervent Radiol 1989;1:23–8.
[8] Williams DE, Pariolero PC, Davis CS, et al. Survival of patients surgically treated for stage I lung cancer. J Thorac Cardiovasc Surg 1981;82:70–6.
[9] Naruke T, Goya T, Tsuchiya R, et al. Prognosis and survival in resected lung carcinoma based on the new international staging system. J Thorac Cardiovasc Surg 1988;15:440–7.
[10] Rusch VW, Giroux DJ, Kraut MJ, et al. Induction chemoradiation and surgical resection for superior sulcus non-small-cell lung carcinomas: long-term results of Southwest Oncology Group Trial 9416 (Intergroup Trial 0160). J Clin Oncol 2007 Jan 20;25(3):313–8.
[11] Akata S, Kajiwara N, Park J, Yoshimura M, Kakizaki D, et al. Evaluation of chest wall invasion by lung cancer using respiratory dynamic MR imaging. J Med Imaging Radiat Oncol 2008;52(February (1)):36–9.
[12] Travis W, Coblby T, Corrin B, Shimosato Y, Brambilla E. Histological typing of lung and pleural tumors. 3rd edition Berlin: Springer Verlag; 1999.
[13] Sobin L, Wittekind C. Cancer IUA. In: TNM classification of malignant tumors. 5th edition New York: Wiley-Liss; 1997.
[14] The Japan Lung Cancer Society. General rule for clinical and pathological record of lung cancer, vol. 95, 6th edition; 2003. pp. 168–169.
[15] Pennes DR, Glazer GM, Wimbish KJ, et al. Chest wall invasion by lung cancer: limitations of CT evaluation. AJR 1985;144:507–11.
[16] Pearlberg JL, Sandler MA, Beute GH, et al. Limitations of CT in evaluation of neoplasms involving chest wall. J Comput Assist Tomogr 1987;11:290–3.
[17] Scott IR, Mueller NL, Miller RR, et al. Resectable stage III lung cancer: CT, surgical, and pathologic correlation. Radiology 1988;166:75–9.
[18] Shin MS, Anderson SD, Myers J, et al. Pitfalls in CT evaluation of chest wall invasion by lung cancer. J Comput Assist Tomogr 1986;10:136–8.
[19] Shiotani S, Sugimura K, Sugihara M, et al. Diagnosis of chest wall invasion by lung cancer: useful criteria for exclusion of the possibility of chest wall invasion with MR imaging. Radiat Med 2000;18(September–October (5)):283–90.
[20] Murata K, Takahashi M, Mori M, et al. Chest wall and mediastinal invasion by lung cancer: evaluation with multisection expiratory dynamic CT. Radiology 1994;191:251–5.
[21] Suzuki N, Saitoh T, Kitamura S. Tumor invasion of the chest wall in lung cancer: diagnosis with US. Radiology 1993;187:39–42.
[22] Yokoi K, Mori K, Miyazawa N, et al. Tumor invasion of the chest wall and mediastinum in lung cancer: evaluation with pneumothorax CT. Radiology 1991;181:147–52.
[23] Orlacchio A, Schillaci O, Antonelli L, et al. Solitary pulmonary nodules: morphological and metabolic characterisation by FDG-PET-MDCT. Radiol Med (Torino) 2007;112(March (2)):157–73. Epub 2007 March 19.
[24] Wong CY, Schmidt J, Bong JS, et al. Correlating metabolic and anatomic responses of primary lung cancers to radiotherapy by combined F-18 FDG PET-CT imaging. Radiat Oncol 2007 May 23;2:18.
[25] Di Donna A, Bazzocchi M, Dolcet F, et al. CT-guided transthoracic needle aspiration of solitary lung lesions. Personal experience in 118 cases. Radiol Med (Torino) 1995 Mar;89(3):287–94.
[26] Wallace MJ, Krishnamurthy S, Broemeling LD, et al. CT-guided percutaneous fine-needle aspiration biopsy of small (< or =1-cm) pulmonary lesions. Radiology 2002;225(December (3)):823–8.
[27] Geraghty PR, Kee ST, McFarlane G, et al. CT-guided transthoracic needle aspiration biopsy of pulmonary nodules: needle size and pneumothorax rate. Radiology 2004;232(July (1)):305, discussion 305–6.

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ORIGINAL ARTICLE

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National structure of radiation oncology in Japan with special reference to designated cancer care hospitals

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Abstract

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

Methods. The Japanese Society of Therapeutic Radiology and Oncology (JASTRO) conducted a questionnaire survey about the national structure of radiation oncology in 2005. In the current study, the structures of 326 designated cancer care hospitals and the other 386 radiotherapy facilities in Japan were compared.

Results. Designated cancer care hospitals accounted for 45.3% of all radiotherapy facilities. The patterns of equipment and personnel in designated cancer care hospitals and the other radiotherapy facilities were as follows: linear accelerators/facility, 1.2 and 1.0; dual-energy function, 73.1% and 56.3%; three-dimensional conformal radiotherapy function, 67.5% and 52.7%; intensity-modulated radiotherapy function, 30.0% and 13.9%; annual number of patients/linear accelerator, 289.7 and 175.1; ^{192}Ir remote-controlled afterloading systems, 27.6% and 8.6%; and average number of full-time equivalent radiation oncologists/facility, 1.4 and 0.9 ($P < 0.0001$). There were significant differences in equipment and personnel between the two types of facilities. Annual patient loads/full-time equivalent radiation oncologist in the designated cancer care hospitals and the other radiotherapy facilities were 252 and 240. Geographically, the number of designated cancer care hospitals was associated with the population, and the number of JASTRO-certified physicians was associated with the number of patients undergoing radiotherapy.

Conclusion. The Japanese structure of radiation oncology in designated cancer care hospitals was more mature than that in the other radiotherapy facilities in terms of equipment, although a shortage of personnel still exists. The serious understaffing problem in radiation oncology should be corrected in the future.

Key words Radiotherapy · Medical Engineering Epidemiology

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Introduction

In Japan, the Cancer Control Act was implemented in 2007 in response to patients' urgent petitions to the government. This law strongly advocates the promotion of radiotherapy (RT) and an increase in the number of radiation oncologists (ROs) and medical physicists. At the same time, the Ministry of Health, Labour and Welfare began the accreditation of "designated cancer care hospitals" with the aim of correcting regional differences in the quality of cancer care and strengthening cooperation among regional cancer care hospitals. The Japanese Society of Therapeutic Radiology and Oncology (JASTRO) has conducted national structure surveys of RT facilities in Japan every 2 years since 1990.[1] The structure of radiation oncology in Japan has improved in terms of equipment and functions in accordance with the increasing number of cancer patients who require RT. Public awareness of the importance of RT is gradually expanding due to the above law. We introduced Patterns of Care Study (PCS) in Japan in 1996; these studies have been carried out every 4 years and have disclosed significant differences in the quality of RT according to the types of facilities and their caseloads.

In the present study, the structure of radiation oncology in designated cancer care hospitals in Japan was investigated in terms of equipment, personnel, patient load, and geographic distribution, and compared with these features of other RT facilities in Japan.

Materials and methods

JASTRO carried out a national structure survey of radiation oncology in 2005, in the form of a questionnaire, between March 2006 and February 2007.[2,3] The questionnaire consisted of questions about the number of treatment machines and modality by type, the number of personnel by job category, and the number of patients by type and the disease site. The response rate was 712 of 735 (96.9%) from all actual RT facilities in Japan.

The number of facilities certified by the Ministry of Health, Labour and Welfare as designated cancer care hospitals by the end of fiscal 2007 was 351. Of the total 351 facilities, 47 were designated prefectural cancer care hospitals and 304 were designated regional cancer care hospitals. Three hundred and fifty-three facilities, including the National Cancer Center Hospital and the National Cancer Center Hospital East were included in this group as designated cancer care hospitals. Seven facilities did not return the survey data, and 20 facilities did not have departments of RT at that point in the survey. The structures of 326 designated cancer care hospitals and the other 386 RT facilities were then analyzed. SAS 8.02[4] (SAS Institute, Cary, NC, USA) was used for the statistical analysis. The statistical significance was tested by means of a χ^2 test, Students' t-test, or analysis of variance (ANOVA).

The Japanese Blue Book guidelines[5] were used as the standard of comparison with the results of this study. These guidelines show the guidelines for the structure of radiation oncology in Japan based on PCS data.[5,6] The standard guidelines for annual patient load/external beam equipment were set at 250–300 (warning level 400); those for annual patient load /full-time equivalent (FTE) radiation oncologist (RO) were set at 200 (warning level 300), and those for annual patient load /FTE RT technologists at 120 (warning level 200).[5,6]

Results

Current situation of radiation oncology in designated cancer care hospitals and the other RT facilities in Japan

Table 1 shows the numbers of new patients and total numbers of patients (new plus repeats) requiring RT in 2005 at the total number of surveyed designated cancer care hospitals and other RT facilities in Japan (n = 712). Designated cancer care hospitals accounted for 45.3% (333/735) of all the RT facilities in Japan. The numbers of new patients and total numbers of patients in all the RT facilities in Japan were estimated at approximately 162 000 (156 318*735/712) and 198 000 (191 173*735/712), respectively (see Table 1 footnote). In designated cancer care hospitals, the corresponding numbers of patients were approximately 99 000 (96 558*333/326) and 121 000 (118 548*333/326), respectively (see Table 1 footnote). The number of patients in designated cancer care hospitals accounted for 61.1% of the number of patients in all RT facilities, for both new patients and the total number of patients (99 000/162 000 and 121 000/198 000; see Table 1 footnote). The average numbers of new patients/facility were 296.2 for designated cancer care hospitals and 154.8 for the other RT facilities, respectively (P < 0.0001). For the average numbers of total

Table 1. The numbers of new patients and total patients (new plus repeat) requiring radiotherapy (RT) in designated cancer care hospitals and the other RT facilities

	Designated cancer care hospitals	Other RT facilities	P value	Total
Facilities	326	386		712
New patients	96558[a]	59760		156318[b]
Average no. new patients/facility	296.2	154.8	<0.0001	219.5
Total patients (new + repeat)	118548[a]	72625		191173[b]
Average no. total patients/facility	363.6	188.1	<0.0001	268.5

[a]The number of designated cancer care hospitals with RT was 333, and the number of new patients in designated cancer care hospitals was estimated at approximately 99000 (96558*333/326); the corresponding number of total patients (new plus repeat) was 121000 (118548*333/326)
[b]The number of RT facilities was 735 in 2005, and the number of new patients was estimated at approximately 162000 (156318*735/712); the corresponding number of total patients (new plus repeat) was 198000 (191173*735/712)

patients/facility, the corresponding data were 363.6 and 188.1, respectively ($P < 0.0001$).

Table 2 shows the equipment patterns, staffing patterns, and patient loads in designated prefectural cancer care hospitals and designated regional cancer care hospitals. There were significant differences in the average number of linear accelerators (Linacs)/facility, the ownership of the intensity-modulated RT (IMRT) function of the Linac, the average number of patients/facility, the average number of patients/Linac, the number of ^{192}Ir remote-controlled afterloading systems (RALSs) ($P < 0.0001$), and the number of computed tomography (CT) simulators in the two types of facilities ($P = 0.0015$). The IMRT function does not necessarily mean its actual use in 2005, but its availability as equipment. The average numbers of FTE ROs/facility were 3.1 for designated prefectural cancer care hospitals and 1.2 for designated regional cancer care hospitals ($P < 0.0001$). The average numbers of JASTRO-certified physicians/facility were 2.1 and 0.7 ($P < 0.0001$).

Facility and equipment patterns and patient load/Linac in designated cancer care hospitals and the other RT facilities

Table 3 shows the RT equipment patterns and related functions in the designated cancer care hospitals and the other RT facilities. In the designated cancer care hospitals, 397 Linacs, 7 telecobalt machines, 17 Gamma Knife machines, 46 ^{60}Co RALSs, and 91 ^{192}Ir RALSs were actually used. In the other RT facilities, the corresponding data were 368, 4, 31, 18, and 28, respectively. The ownership of equipment in designated cancer care hospitals, excluding telecobalt machines and Gamma Knife machines, was significantly higher than that in the other RT facilities (Linac, $P = 0.0002$; other equipment, $P < 0.0001$). In designated cancer care hospitals, the Linac system used dual-energy function in 291 systems (73.1%), three-dimensional conformal RT function (3DCRT) in 268 (67.5%), and IMRT function in 119 (30.0%). In the other RT facilities, the corresponding data

Table 2. Equipment patterns, staffing patterns, and patient loads in designated prefectural cancer care hospitals and designated regional cancer care hospitals

	Designated prefectural cancer care hospitals ($n = 49$)		Designated regional cancer care hospitals ($n = 277$)		P value
	n	%	n	%	
Linac	87	100.0[a]	310	95.7[a]	0.1377
With IMRT function	46	52.9[b]	73	23.5[b]	<0.0001
No. Linacs/facility	1.8		1.1		<0.0001
Annual no. patients/facility	722.3		300.2		<0.0001
Annual no. patients/Linac	406.8[c]		257.0[c]		<0.0001
^{192}Ir RALS (actual use)	37	75.5	54	8.6	<0.0001
No. of CT simulators	47	83.7[c]	170	59.9[c]	0.0015
Average no. of FTE ROs/facility	3.1		1.2		<0.0001
Average no. of JASTRO-certified ROs/facility	2.1		0.7		<0.0001

Linac, Linear accelerator; IMRT, intensity-modulated RT; RALS, remote-controlled afterloading system; CT, computed tomography; FTE, full-time equivalent (40 h/week only for RT practice); RO, radiation oncologist; JASTRO, Japanese Society of Therapeutic Radiology and Oncology

[a] Percentage calculated from the number of systems using this function and the total number of Linac systems

[b] Percentage calculated from the number of patients and the number of Linac systems. Facilities without Linacs were excluded from the calculation

[c] Percentage of facilities which have equipment

Table 3. Equipment, its function, and patient load per equipment in designated cancer care hospitals and the other RT facilities

	Designated cancer care hospitals ($n = 326$)		Other RT facilities ($n = 386$)		P-value	Total ($n = 712$)	
	n	%	n	%		n	%
Linac	397	96.3[a]	368	88.9[a]	0.0002	765	92.3[a]
With dual-energy function	291	73.1[b]	207	56.3[b]	<0.0001	498	65.1[b]
With 3D-CRT function (MLC width =<1.0 cm)	268	67.5[b]	194	52.7[b]	<0.0001	462	60.4[b]
With IMRT function	119	30.0[b]	51	13.9[b]	<0.0001	170	22.2[b]
Average no. Linacs/facility	1.2		1.0		<0.0001	1.1	
Annual no. patients/Linac	289.7[c]		175.1[c]		<0.0001	234.6[c]	
Telecobalt (actual use)	18 (7)		16 (4)			34 (11)	
Gamma Knife	17		31		0.1400	48	
^{60}Co RALS (actual use)	51 (46)	15.6 (14.1)	23 (18)	7.1[c] (5.5)	<0.0001	74 (64)	10.4[c] (9.0)
^{192}Ir RALS (actual use)	94 (91)	28.5[c] (27.6)	29 (28)	8.9[c] (8.6)	<0.0001	123 (119)	17.1[c] (16.6)

3D-CRT, three-dimensional conformal RT; other abbreviations as in Table 2

[a] Percentage of facilities which have this equipment (two or more pieces of equipment per facility)

[b] Percentage calculated from the number of systems using this function and the total number of Linac systems

[c] Percentage calculated from the number of patients and the number of Linac systems. Facilities without Linacs were excluded from the calculation

were 207 (56.3%), 194 (52.7%), and 51 (13.9%), respectively. The functions of Linac showed significant superiority, approximately 15% greater, in designated cancer care hospitals compared with the other RT facilities ($P < 0.0001$). The patient loads/Linac were 289.7 for designated cancer care hospitals and 175.1 for the other RT facilities ($P < 0.0001$). Fig. 1 shows the distribution of annual patient load/Linac in designated cancer care hospitals and the other RT facilities. Eighteen percent of designated cancer care hospitals and 6% of the other RT facilities were subject to treatment that exceeded the warning level of the Japanese Blue Book Guidelines,[5] of 400 patients/Linac. However, the average patient load/Linac in the other RT facilities was less than the guideline level.

Table 4 shows the RT planning and other equipment patterns. X-ray simulators were installed in 79.1% of the designated cancer care hospitals and 61.7% of the other RT facilities. CT simulators were installed in 63.5% and 48.4%, respectively. A noteworthy difference was found between designated cancer care hospitals and the other RT facilities in the rate of X-ray simulator and CT simulator installation ($P < 0.0001$). Only a very few facilities owned magnetic resonance imaging (MRI) equipment for the RT department, although computer use for RT recording was pervasive in both designated cancer care hospitals and the other RT facilities.

Staffing patterns and patient loads in designated cancer care hospitals and the other RT facilities

Table 5 shows the staffing patterns and patient loads in designated cancer care hospitals and the other RT facilities. We found that 50.3% of the designated cancer care hospitals and 31.9% of the other RT facilities had their own designated RT beds, and ROs also had to care for their inpatients. The total numbers of FTE ROs were 471.3 for the designated cancer care hospitals and 303.2 for the other RT facilities. The average numbers of FTE ROs/facility were 1.4 and 0.9, respectively ($P < 0.0001$). The patient loads/FTE RO were 251.5 and 239.6. Fig. 2 shows the distribution of annual patient load/FTE RO in designated cancer care hospitals and the other RT facilities. Twenty-four percent of designated cancer care hospitals and 11% of the other RT facilities treated more than 300 patients/RO, which exceeded the warning level of the Japanese Blue Book Guidelines.[5] Fig. 3 shows the percentage of facilities by patient load/FTE RO. The largest number of facilities featured a patient/FTE RO level in the 150–199 range for designated cancer care hospitals and in the 100–149 range for the other RT facilities. The second largest numbers featured patient/FTE RO levels in the 200–249 and 50–99 ranges, respectively. Facilities that had less than 1 FTE RO

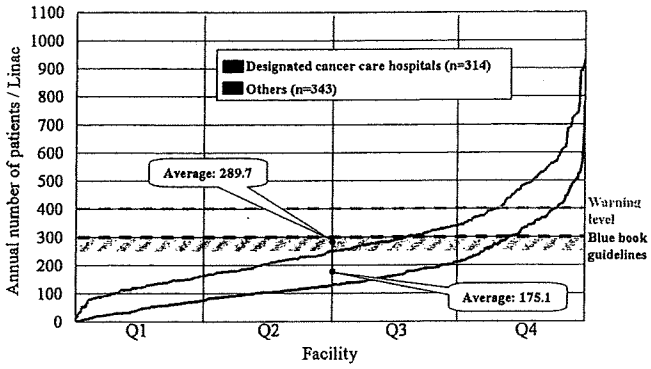

Fig. 1. Distribution of annual patient load/linear accelerator (*Linac*) in designated cancer care hospitals and the other radiotherapy (RT) facilities (*others*). *Horizontal axis* represents facilities arranged in order of increasing annual number of patients/Linac within facilities. The above-mentioned facilities are divided in quaters; *Q1*, 0%–25%; *Q2*, 26%–50%; *Q3*, 51%–75%; *Q4*, 76%–100%

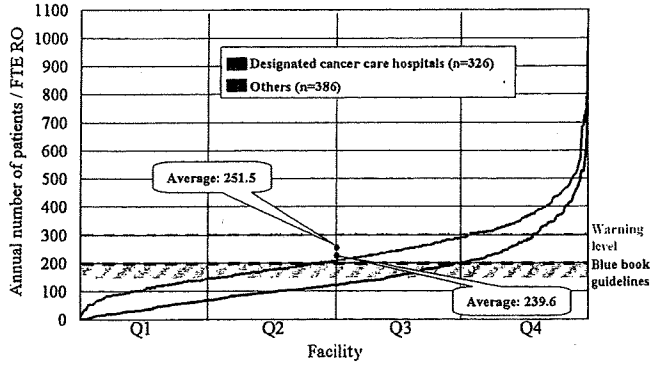

Fig. 2. Distribution of annual patient load/ full-time equivalent radiation oncologist (*FTE RO*) in designated cancer care hospitals and the other RT facilities. *Horizontal axis* represents facilities arranged in order of increasing annual numbers of patients / FTE RO within facilities. The number of FTE ROs for facilities with less than one FTE was calculated as FTE = 1 to avoid overestimating patient load / FTE RO. *Q1-Q4*, as in Fig. 1 legend

Table 4. Radiotherapy planning and other equipment in designated cancer care hospitals and the other RT facilities

	Designated cancer care hospitals ($n = 326$)		Other RT facilities ($n = 386$)		*P*-value	Total ($n = 712$)	
	n	%	*n*	%		*n*	%
X-ray simulator	262	79.1[a]	240	61.7[a]	<0.0001	502	69.7[a]
CT simulator	217	63.5[a]	190	48.4[a]	<0.0001	407	55.3[a]
RTP computer (>= 2)	510 (101)	96.3[a] (38.5)	430 (45)	90.4[a] (11.7)	0.0019 (<0.0001)	940 (146)	93.1[a] (20.5)
MRI (>= 2)	588 (203)	97.5[a] (77.5)	524 (135)	92.2[a] (35.0)	0.0017 (<0.0001)	1112 (338)	94.7[a] (47.5)
For RT only	6	1.8[a]	6	1.6[a]	–	12	1.7[a]
Computer use for RT recording	298	91.4[a]	328	85.0[a]	0.0086	626	87.9[a]

RTP, RT planning; MRI, magnetic resonance imaging; RT, radiotherapy; other abbreviations as in Table 2
[a]Percentage of institutions which have equipment (two or more pieces of equipment per institution)

Table 5. Staffing patterns and patient loads in designated cancer care hospitals and the other RT facilities

	Designated cancer care hospitals (n = 326)	Other RT facilities (n = 386)	P-value	Total (n = 712)
Facilities with RT beds	164 (50.3)	123 (31.9)		287 (40.3)
Average no. RT beds/facility	4.8	3.0	0.0001	3.6
Total (full-time + part-time) FTE ROs	471.3	303.2		774.5
Average no. FTE ROs/facility	1.4	0.9	<0.0001	1.1
No. of JASTRO-certified ROs (full-time)	293	133		426
Average no. JASTRO-certified ROs/facility	0.9	0.4	<0.0001	0.6
Patient load/FTE RO	251.5	239.6	0.0641	246.8
Total no. of RT technologists	889.9	744.6		1634.5
Average no. of RT technologists/facility	2.7	2.3	<0.0001	2.3
Patient load/RT technologist	133.2	97.5	<0.0001	117.0
Full-time medical physicists + part-time	65.0 + 17.1	52.0 + 13.0		117.0 + 30.1
Full-time RT QA staff + part-time	156.0 + 8.0	100.8 + 5.0		256.8 + 13.0
Total no. of nurses/assistants/clerks	476.8	430.2		907.0

Data values in parentheses are percentages
QA, quality assurance; other abbreviations as in Table 2

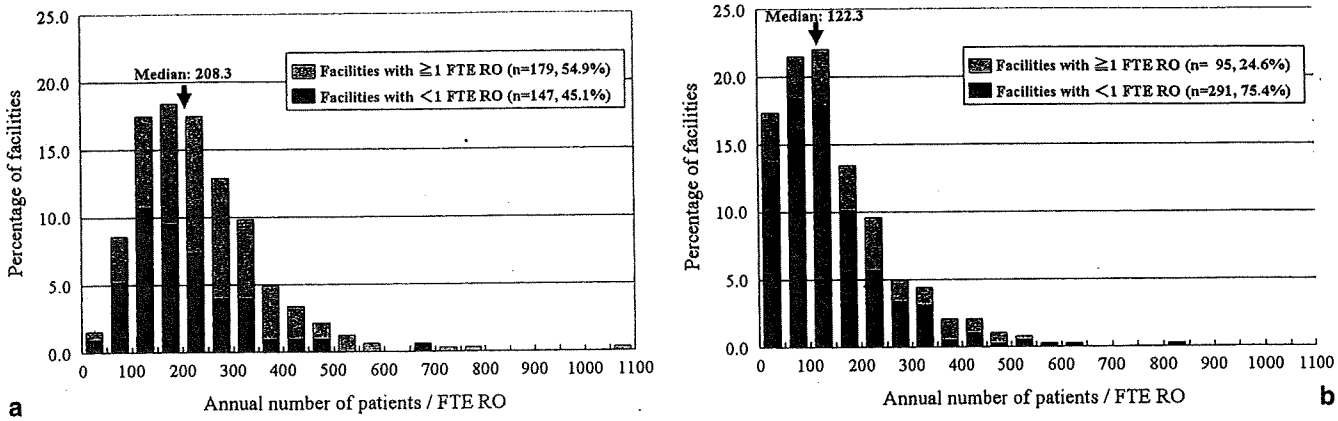

Fig. 3. **a** Percentage of facilities by patient load / FTE RO in designated cancer care hospitals. *Each bar* represents an interval of 50 patients per FTE RO. The number of FTE ROs for facilities with less than one FTE was calculated as FTE = 1 to avoid overestimating patient load / FTE RO. **b** Percentage of facilities by patient load / FTE RO in the other RT facilities. *Each bar* represents an interval of 50 patients per FTE RO. The number of FTE ROs for facilities with less than one FTE was calculated as FTE = 1 to avoid overestimating patient load / FTE RO

still accounted for about 45.1% of designated cancer care hospitals and 75.4% of the other RT facilities.

The total numbers of RT technologists were 889.9 for designated cancer care hospitals and 744.6 for the other RT facilities. The average numbers of RT technologists in the two types of facilities were 2.7 and 2.3, respectively (P < 0.0001). The patient loads/RT technologist were 133.2 and 97.5, respectively (P < 0.0001). Fig. 4 shows the distribution of annual patient load/RT technologist in designated cancer care hospitals and the other RT facilities. Fourteen percent of designated cancer care hospitals and 8% of the other RT facilities treated more than 200 patients per RT technologist, exceeding the warning level of the Japanese Blue Book Guidelines.[5] Fig. 5 shows the percentage of facilities by patient load/RT technologist. The largest number of facilities featured a patient/RT technologist level in the 80–99 range for both designated cancer care hospitals and the other RT facilities. The second largest numbers featured patient/RT technologist levels in the ranges of 100–119 and 60–79, respectively.

There were 65.0 FT (and 17.1 part-time) medical physicists for designated cancer care hospitals and 52.0 FT (and

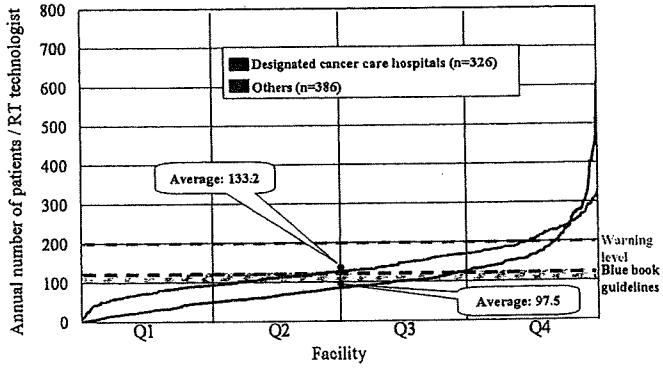

Fig. 4. Distribution of annual patient load / RT technologist in designated cancer care hospitals and the other RT facilities. *Horizontal axis* represents facilities arranged in order of increasing annual number of patients / RT technologist within facilities. *Q1-Q4*, As in Fig. 1 legend

13.0 part-time) medical physicists for the other RT facilities. There were 156.0 FT (and 8.0 part-time) RT quality assurance staff for designated cancer care hospitals and 100.8 FT (and 5.0 part-time) RT quality assurance staff for the other

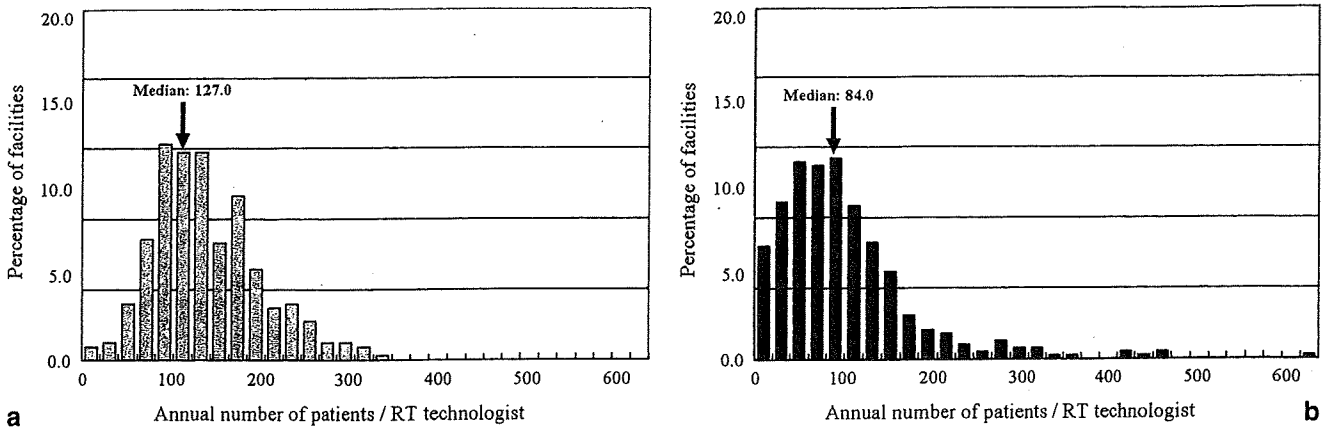

Fig. 5. **a** Percentage of facilities by patient load / RT technologist in designated cancer care hospitals. *Each bar* represents an interval of 20 patients per FTE staff. **b** Percentage of facilities by patient load / RT technologist in the other RT facilities. *Each bar* represents an interval of 20 patients per FTE staff

Table 6. Primary disease sites, and brain metastasis and bone metastasis treated with RT in designated cancer care hospitals and the other RT facilities

Primary site	Designated cancer care hospitals (n = 321)		Other RT facilities (n = 380)		P-value	Total (n = 701)	
	n	%	n	%		n	%
Cerebrospinal	4130	4.3	4469	7.7	<0.0001	8599	5.6
Head and neck (including thyroid)	11199	11.6	5174	8.9	<0.0001	16373	10.6
Esophagus	6647	6.9	3566	6.1	<0.0001	10213	6.6
Lung, trachea, and mediastinum	18097	18.8	11943	20.5	<0.0001	30040	19.4
Lung	15341	15.9	10051	17.3	<0.0001	25392	16.4
Breast	18733	19.4	11528	19.8	0.0458	30261	19.6
Liver, biliary, tract, and pancreas	4116	4.3	2239	3.9	<0.0001	6355	4.1
Gastric, small intestine, and colorectal	4868	5.0	2976	5.1	0.5193	7844	5.1
Gynecologic	6277	6.5	2392	4.1	<0.0001	8669	5.6
Urogenital	11380	11.8	7180	12.4	0.0011	18560	12.0
Prostate	8133	8.4	5085	8.7	0.0291	13218	8.6
Hematopoietic and lymphatic	5499	5.7	2541	4.4	<0.0001	8040	5.2
Skin, bone, and soft tissue	3326	3.4	1878	3.2	0.0223	5204	3.4
Other (malignant)	1165	1.2	910	1.6	<0.0001	2075	1.3
Benign tumors	1033	1.1	1323	2.3	<0.0001	2356	1.5
Pediatric <15 years (included in totals above)	577	0.6	470	0.8	<0.0001	1047	0.7
Total	96470	100.0	58119	100.0	<0.0001	154589[a]	100.0
Metastasis	(n = 326)		(n = 386)		P-value	(n = 712)	
Brain	7212	6.1	8109	11.2	<0.0001	15321	8.0
Bone	16968	14.3	10508	14.5	0.3464	27476	14.4

[a]Total number of new patients was different from this number, because no data on primary sites were reported by some facilities

RT facilities. Finally, there were 476.8 nurses and clerks for designated cancer care hospitals and 430.2 nurses and clerks for the other RT facilities.

Distribution of primary disease sites and palliative treatment in designated cancer care hospitals and the other RT facilities

Table 6 shows the distribution of primary disease sites and palliative treatment in the designated cancer care hospitals and the other RT facilities. The most common disease site in designated cancer care hospitals was the breast; in the other RT facilities, it was lung/bronchus/mediastinum. Head/neck, esophagus, liver/biliary tract/pancreas, gynecologic, hematopoietic/lymphatic, and skin/bone/soft tissue cancers were treated at higher rates at designated cancer care hospitals than at the other RT facilities (skin/bone/soft tissue cancer, $P = 0.0223$; other cancers, $P < 0.0001$). The other RT facilities treated more patients with brain metastasis (11.2% of all new patients) than the designated cancer care hospitals ($P < 0.0001$).

Geographic patterns in designated cancer care hospitals and the other RT facilities

Fig. 6 a,b shows the geographic distribution, for 47 prefectures, of the number of RT facilities arranged in order of increasing population by all prefectures in Japan (Fig. 6a)

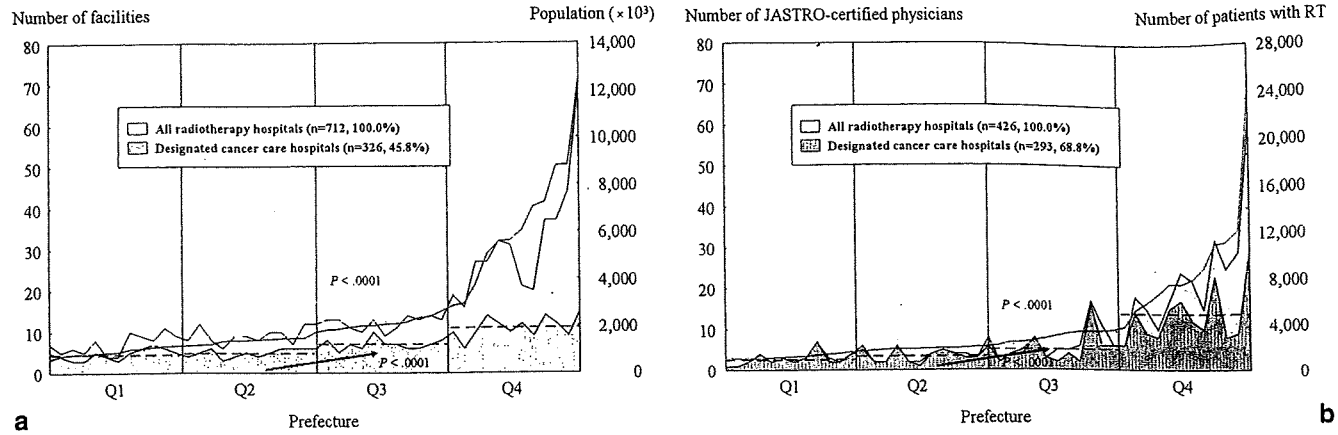

Fig. 6. **a** Geographic distribution, for 47 prefectures, of the number of facilities arranged in order of increasing population. *Upper dashed horizontal bar* shows average number of facilities in the prefectures per 4 separated groups (Q1–Q4) in all RT hospitals, and *lower dashed horizontal bar* shows that number in designated cancer care hospitals. **b** Geographic distribution, for 47 prefectures, of the number of Japanese Society of Therapeutic Radiology and Oncology (*JASTRO*)-certified physicians, arranged in increasing order of the number of patients undergoing RT, by prefecture. *Upper horizontal dashed bar* shows average number of JASTRO-certified physicians in the prefectures per quarter in all RT hospitals, and *lower dashed horizontal bar* shows that number in designated cancer care hospitals. *Q1-Q4*, As in Fig. 1 legend

and the number of JASTRO-certified physicians, arranged in order of increasing number of patients undergoing RT, by all prefectures in Japan (Fig. 6b).[7] The average number of RT facilities per 4 separated groups (Q1–Q4) ranged from 7.2 to 32.9 in all RT facilities in Japan. In designated cancer care hospitals, these numbers ranged from 4.7 to 11.2. There were significant differences in the average number of facilities per quarter in both all RT facilities and in designated cancer care hospitals (both, $P < 0.0001$). The average number of JASTRO-certified physicians per quarter ranged from 2.8 to 24.5 in all RT facilities in Japan. In designated cancer care hospitals, these numbers ranged from 2.8 to 14.0. The average number of JASTRO-certified physicians per quarter showed significant differences in both all RT facilities and designated cancer care hospitals (both, $P < 0.0001$).

Discussion

The number of patients in designated cancer care hospitals was 61.1% of the number of patients (both new patients and the total number of patients) in all RT facilities in Japan, although the designated cancer care hospitals accounted for 45.3% of all RT facilities. About 62 % of all RT facilities have less than 1 FTE RO, while about 45% of designated cancer care hospitals have less than 1 FTE RO. In Japan, the majority of facilities still rely on part-time ROs, especially in the facilities other than the designated cancer care hospitals. The percentage distribution of facilities by patient load/RO in designated cancer care hospitals proved to be largely similar to that of the United States in 1989.[8] However, facilities which have less than 1 FTE RO still account for about 45% of designated cancer care hospitals in Japan. In the United States, all facilities are supported by a full-time RO. The percentage distribution of facilities by patient load/RO in the other RT facilities in the present study was largely similar to that found in Japan in 1990,[8] so a shortage of ROs will remain a major concern in Japan. As for medical physicists, their numbers in Japan are still smaller than those in Europe and the United States. They work mainly in metropolitan areas or academic facilities such as university hospitals or cancer centers. At present, there is no national license for a medical physicist in Japan. Those with a master's degree in science or engineering or radiology technologists with enough clinical experience can take the Japan Radiological Society (JRS)-certified examination to become medical physicists. In Japan, a new educational system is developing to train specialists for cancer care, including medical physicists, medical oncologists, oncology nurses, and palliative care doctors. A sufficient number of RT technologists is ensured, as compared with ROs and medical physicists. However, RT technologists are busy, because they also partly play the role of medical physicists in Japan.

In terms of the distribution of the primary disease site for RT, designated cancer care hospitals treated more patients with head and neck cancers, while the other RT facilities treated more patients with cancers of the lung, trachea, and mediastinum Furthermore, more patients with brain or bone metastasis were treated in the other RT facilities. These results imply that designated cancer care hospitals which treat more potentially curative patients have better structures than the other hospitals.

On a regional basis, the number of all RT facilities and the number of designated cancer care hospitals were strongly associated with population (correlation coefficients were 0.95 and 0.83). These results proved that designated cancer care hospitals were in the appropriate places. However, in some regions where there was a large population, the proportion of designated cancer care hospitals was not sufficient, because many university hospitals were not certified by the Ministry of Health, Labour and Welfare as designated cancer care hospitals. There were two prefectures where the number of RT hospitals was extremely small, as

shown in the Q4 region of Fig. 6a. They were located in metropolitan areas, so many cancer patients who lived in those areas might have received treatment in the hospitals in Tokyo. The numbers of JASTRO-certified physicians in all RT facilities and in the designated cancer care hospitals were also strongly associated with the number of patients undergoing RT (correlation coefficients were 0.92 and 0.83). The JASTRO-certified physicians were in the appropriate places. However, the absolute number of JASTRO-certified physicians was especially insufficient in regions where there were many patients undergoing RT. As shown in Fig. 6b, there were five peaks in the number of JASTRO-certified physicians in the Q3 and Q4 regions. These peaks were Tokyo, Kanagawa, Chiba, Hiroshima, and Gunma, in descending order. In the Tokyo metropolitan area, the Keihanshin area, and the Chukyo area, cancer patients can easily receive treatment at hospitals that are in other regions because these areas are conveniently located in terms of public transpotation (indicated by the jagged graph in Fig. 6b). In Japan, it is necessary to increase the number of designated cancer care hospitals and the number of JASTRO-certified physicians in regions where there is a large population and many patients.

The utilization rate of RT for new cancer patients in Japan remains at about 25% (162 000/660 578[9]), less than half the ratio in the United States and European countries. The "anti-cancer" law was enacted in Japan to promote RT and education for ROs, medical physicists, and other staff members as of April 2007. In Japan, RT is expected to play an increasingly important role because the increase in the elderly population is the highest among other developed countries.

In the present study, the ownership of all equipment was more firmly in place in designated cancer care hospitals than in the other RT facilities.[10] The function of Linac, in particular the IMRT function, does not mean actual use of its function. In 2005, mainly due to severe shortages of personnel, only 6.0% of Linacs with their function were used for actual IMRT in the clinic. The average number of staff members for RT in designated cancer care hospitals was more than that in the other RT facilities. So, the accreditation of designated cancer care hospitals is closely correlated with the maturity of the structures of radiation oncology.[10] However, it is problematic that there are designated cancer care hospitals without their own RT departments. We consider that all the designated cancer care hospitals need to have their own RT departments, because the number of cancer patients requiring RT is rapidly increasing and currently RT in Japan is underutilized compared with that in Europe and the United States. The accreditation of designated cancer care hospitals by the Ministry of Health, Labour and Welfare would be a good start to consolidate RT facilities geographically in Japan.

The structural information on all RT facilities in Japan is regularly surveyed by JASTRO. Although the process and the outcome of cancer care in patients undergoing RT have been investigated by PCS every 4 years, the collection of the outcome information is insufficient. In the United States, a National Cancer Database was established and it has been collecting the data for cancer care. This database is used as the quality indicator for improvements in the processes and outcomes of cancer care. It is necessary to establish an informational system in Japan that can collect national data for cancer care. We have now established a Japanese National Cancer Database based on the RT data. We are preparing the collection of cancer care data by using this system.

In conclusion, the structure of radiation oncology in designated cancer care hospitals in Japan showed maturity, more so than that of other RT facilities, in terms of equipment and their functions, although a shortage of personnel still exists. It is necessary, as national policy, to solve the problem of the arrangement of designated cancer care hospitals and the shortage of personnel for cancer care as clarified by data in this survey.

Conflict of interest

H. Ikeda received a Grant-in-Aid for Cancer Research (No. 18-2) from the Ministry of Health, Labour and Welfare. The other authors have no conflict of interest.

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References

1. Shibuya H, Tsujii H (2005) The structural characteristics of radiation oncology in Japan in 2003. Int J Radiat Oncol Biol Phys 62:1472–1476
2. Teshima T, Numasaki H, Shibuya H, et al. (2007) Japanese Structure Survey Of Radiation Oncology In 2005 (first report; in Japanese). J Jpn Soc Ther Radiol Oncol 19:181–192
3. Teshima T, Numasaki H, Shibuya H, et al. (2007) Japanese Structure Survey Of Radiation Oncology in 2005 (second report; in Japanese). J Jpn Soc Ther Radiol Oncol 19:193–205
4. SAS Institute (1985) SAS user's guide: statistics. Cary, NC: SAS Institute
5. Japanese PCS Working Group (2005) Radiation oncology in multidisciplinary cancer therapy. Basic structure requirement for quality assurance of radiotherapy based on Patterns of Care Study in Japan. Self-publication supported by the Ministry of Health, Welfare and Labour, of Japan. Ministry of Health, Welfare and Labour, Tokyo
6. Teshima T, Tatsuzaki H, Mitsumori M, et al. (2006) Revision of guideline for structure of radiation oncology by the Patterns of Care Study (in Japanese). J Jpn Soc Ther Radiol Oncol 18:107–112
7. Statistics Bureau, Ministry of Internal Affairs and Communications: the 2005 population census, First basic complete tabulation. Available from: http://www.stat.go.jp/english/data/kokusei/2005/kihon1/00/hyodai.htm. Accessed Jun 30, 2008
8. Teshima T, Owen JB, Hanks GE, et al. (1996) A comparison of the structure of radiation oncology in the United States and Japan. Int J Radiat Oncol Biol Phys 34:235–242
9. Oshima A, Kuroishi T, Tajima K (eds) (2004) Cancer statistics – 2004. Shinohara, Tokyo, p 207
10. Ikeda H, Nishio M, Kataoka M, et al. (2008) Structure analysis of designated hospitals for cancer control in Japan from JASTRP census survey database 2005 (in Japanese). J Jpn Soc Ther Radiol Oncol 20:13–22

全国放射線治療施設の2007年定期構造調査報告(第1報)

JASTROデータベース委員会
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上紺屋 憲彦, 小泉 雅彦, 多湖 正夫, 安藤 裕, 塚本 信宏,
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全国放射線治療施設の2007年定期構造調査報告(第1報)

JASTROデータベース委員会

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JAPANESE STRUCTURE SURVEY OF RADIATION ONCOLOGY IN 2007 (FIRST REPORT)

JASTRO Database Committee

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Abstract: A national structure survey of radiation oncology in 2007 using questionnaires was conducted from March 2008 to January 2009 by JASTRO. The response rate was 721 out of 765 (94.2%) active radiotherapy institutes. The total number of new cancer patients and the total number of cancer patients (new+repeat) treated with radiation were estimated to be approximately 181,000 and 218,000, respectively. The numbers of linac, telecobalt, Gamma Knife®, ^{60}Co RALS, and ^{192}Ir RALS in actual use were 807, 15, 46, 45, and 123, respectively. The linac has a dual energy function in 539 (66.8%), 3DCRT in 555 (68.8%), and IMRT in 235 (29.1%). The numbers of JASTRO-certified radiation oncologists, full time equivalent (FTE) radiation oncologists, medical physicists, radiotherapy QA personnel, radiation therapists, radiation therapy nurses, and clerks were 477, 826 FTE, 64 FTE, 106 FTE, 1,634 FTE, 494 FTE, and 329, respectively. There were significant increases in the use of ^{125}I for prostate cancer patients by 52% and IMRT by 271% between 2005 and 2007. Geographically, there was still a significant variation in the use of radiotherapy from 0.8 new patients per 1,000 population to 1.8 (average 1.3).

Key words: Structure survey, Radiotherapy facility, Radiotherapy equipment, Radiotherapy personnel

はじめに

1990年に恒元らによって第1回日本放射線腫瘍学会(JASTRO)全国放射線治療施設構造調査が実施された[1]. 1993年以降は定期的(2年ごと)に構造調査を学会事業として行っている[2)-10)]. これらのデータ分析によってJASTROは, わが国における放射線治療のおかれている状況を装備, 人員, 患者数などを中心に正確に把握し, 国や地方自治体レベルでの施策の提言や個々の医療機関における構造の改善に役立つ情報を提供してきた. この調査への協力はJASTROによる放射線治療施設の施設認定制度における認定を受けるための必要条件ともなっている.

今回, 2007年を対象とした第9次全国放射線治療施設の構造調査を行った. データはすでにJASTROホームページ(http://www.jastro.jp/)よりdownload可能にしている[11]. 本報告ではこれらのデータを示すとともに, データベース委員会が注目しているデータについて解説と考案を行った. なお, 人員負荷などの詳細な分析は, 第2報以降に報告する.

このデータはJASTROの共有財産であり, 各施設の構造を改善するために利用されることを最終目標としている.

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