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Int. J. Radiation Oncology Biol. Phys., Vol. ■, No. ■, pp. 1–4, 2011

0360-3016/$ - see front matter

ELSEVIER

doi:10.1016/j.ijrobp.2010.11.046

CLINICAL INVESTIGATION

OUTCOMES OF DIFFUSION TENSOR TRACTOGRAPHY–INTEGRATED STEREOTACTIC RADIOSURGERY

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Purpose: To analyze the effect of use of tractography of the critical brain white matter fibers created from diffusion tensor magnetic resonance imaging on reduction of morbidity associated with radiosurgery.
Methods and Materials: Tractography of the pyramidal tract has been integrated since February 2004 if lesions are adjacent to it, the optic radiation since May 2006, and the arcuate fasciculus since October 2007. By visually confirming the precise location of these fibers, the dose to these fiber tracts was optimized. One hundred forty-four consecutive patients with cerebral arteriovenous malformations who underwent radiosurgery with this technique between February 2004 and December 2009 were analyzed.
Results: Tractography was prospectively integrated in 71 of 155 treatments for 144 patients. The pyramidal tract was visualized in 45, the optic radiation in 22, and the arcuate fasciculus in 13 (two tracts in 9). During the follow-up period of 3 to 72 months (median, 23 months) after the procedure, 1 patient showed permanent worsening of preexisting dysesthesia, and another patient exhibited mild transient hemiparesis 12 months later but fully recovered after oral administration of corticosteroid agents. Two patients had transient speech disturbance before starting integration of the arcuate fasciculus tractography, but no patient thereafter.
Conclusion: Integrating tractography helped prevent morbidity of radiosurgery in patients with brain arteriovenous malformations. © 2011 Elsevier Inc.

Arteriovenous malformation, Diffusion tensor tractography, Gamma knife, Morbidity, Stereotactic radiosurgery.

INTRODUCTION

Stereotactic radiosurgery is one of the principal treatment modalities for various kinds of vascular, neoplastic, or functional disorders of the brain (1–4). Although its efficacy is well known, radiation-induced neuropathy occurs in 5–20% of patients (2, 5–8). To minimize such unignorable risk, we have integrated tractography of the brain white matter based on diffusion tensor magnetic resonance imaging before the procedure into treatment planning of radiosurgery using Gamma Knife (9–11). Diffusion tensor tractography, one of the major recent advancements in magnetic resonance imaging, enables clear visualization of various fibers inside the white matter of the brain, which is not visible with use of conventional imaging modalities (12). Clinical applications of diffusion tensor tractography are mainly reported as diagnostic tools, and reports on its therapeutic application are quite limited (10, 13). In this study, we analyzed the effect of integrating diffusion tensor tractography into treatment planning of stereotactic radiosurgery on the reduction of morbidity in a prospective case series with arteriovenous malformations of the brain.

METHODS AND MATERIALS

Our selection criterion for stereotactic radiosurgery was, in principle, small malformations (<3 cm) in critical, or eloquent, areas of the brain (including sensorimotor, language, or visual cortex; the hypothalamus or thalamus; the internal capsule; the brain stem; the cerebellar peduncles; and the deep cerebellar nuclei) that, if injured, result in disabling neurologic deficits (2, 14). We started integrating diffusion tensor tractography of the pyramidal tract in February 2004 because we considered the pyramidal tract to be the most crucial fiber in preventing morbidity of radiosurgery out of complexity of white matter fibers inside the brain. From May 2006, we added the integration of diffusion tensor tractography of the optic radiation, and diffusion tensor tractography of the arcuate fasciculus tractography from October 2007. One hundred forty-four patients with arteriovenous malformations who have consecutively undergone stereotactic radiosurgery using Gamma Knife with this protocol between February 2004 and December

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Conflicts of interest: none.

Received Sept 22, 2010, and in revised form Sept 22, 2010. Accepted for publication Nov 4, 2010.

Table 1. Baseline characteristics of 144 patients treated

Age (y)	35 (5–77)
Female sex	65 (45)
Details of arteriovenous malformations	
Diameter (cm)	2.7 (0.7–7.9)
Small size	89 (62)
Eloquent brain location	66 (46)
Deep venous drainage	74 (51)
Spetzler-Martin grade	II (I–VI)
Details of radiosurgery	
Target volume (cm^3)	6.9 (0.3–24)
Maximal dose (Gy)	40 (32–50)
Dose to margins (Gy)	20 (15–25)
Follow-up period (mo)	23 (3–72)

Data are number (percentage) or median (range).

2009 were enrolled in this study. All patients were considered as candidates for integrating tractography, but the integration was not carried out if a target lesion was considered to be located more than 1 cm apart from these fiber tracts and risk of injuring them was considered to be sufficiently low. Malformations were located in eloquent brain areas in 66 patients (46%). Detailed treatment parameters are shown in Table 1.

Diffusion tensor magnetic resonance imaging was obtained on the day before treatment. Tractography was created from diffusion tensor imaging by using freely shared programs, according to anatomic landmarks as shown in previous studies (9–12).

On the day of treatment, patients were affixed to the stereotactic coordinate frame and underwent stereotactic magnetic resonance imaging and stereotactic cerebral angiography. Stereotactic magnetic resonance imaging and tractography were registered by using the method reported previously (9–11, 15). After the introduction of Gamma Knife 4C in October 2006, the registration process was automated (16). Tractography-integrated images were imported to treatment planning images on the day of radiosurgery. Conformal treatment planning was made by experienced neurosurgeons and radiation oncologists with use of the treatment planning software GammaPlan (Elekta Instruments AB, Stockholm, Sweden). Generally 20 Gy was given to the margin of lesions by using 40–50% isodose lines. Any portion of the anterior visual pathway and half of the brainstem were designed to receive no more than 10 Gy.

The precise location of the pyramidal tract (Fig. 1), the optic radiation (Fig. 2), or the arcuate fasciculus was confirmed on treatment planning images, and it was attempted that the maximum dose received by each fiber was less than 20 Gy, 8 Gy, or 8 Gy (20 Gy in the frontal fibers), respectively, on the basis of previous analyses (9–11), though this was not possible in some cases.

Serial formal neurologic and radiologic examination was performed every 6 months after the procedure.

RESULTS

Diffusion tensor–based tractography was prospectively integrated in 71 (46%) of 155 treatment sessions. Integrated fiber tracts were the pyramidal tract in 45, the optic radiation in 22, and the arcuate fasciculus in 13 sessions, including 9 in which two tracts were integrated (the pyramidal tract and the optic radiation in 2, the pyramidal tract and the arcuate fasciculus in 3, the optic radiation and the arcuate fasciculus in 4). The optic radiation could not be depicted in 1 patient, and only arcuate fasciculus was drawn. Of 71 treatments with integration of tractography, the distance between the lesion and critical white matter fibers was less than 5 mm in 43 (60%); thus, tighter treatment planning was mandatory. Consequently, 39 sessions (55%) necessitated any modification in treatment planning by reducing the radiation dose to the visualized tracts. Until December 2007, 38% of treatments (37 of 98 sessions) were performed with integration of tractography, whereas tractography was integrated for 60% (34 of 57) thereafter. This difference in frequency was statistically significant according to χ^2 test ($p = 0.008$).

Two patients died of unknown cause after the procedure. The other 142 patients were followed for 3–72 months (median, 23 months) after radiosurgery. During this period, transient speech disturbance was observed in 2 patients. They were treated before 2007, when we started integrating arcuate fasciculus tractography. One patient with right thalamic arteriovenous malformation showed gradual worsening of pre-existing dysesthesia of left upper and lower extremities after treatment, and this symptom lasted until the last

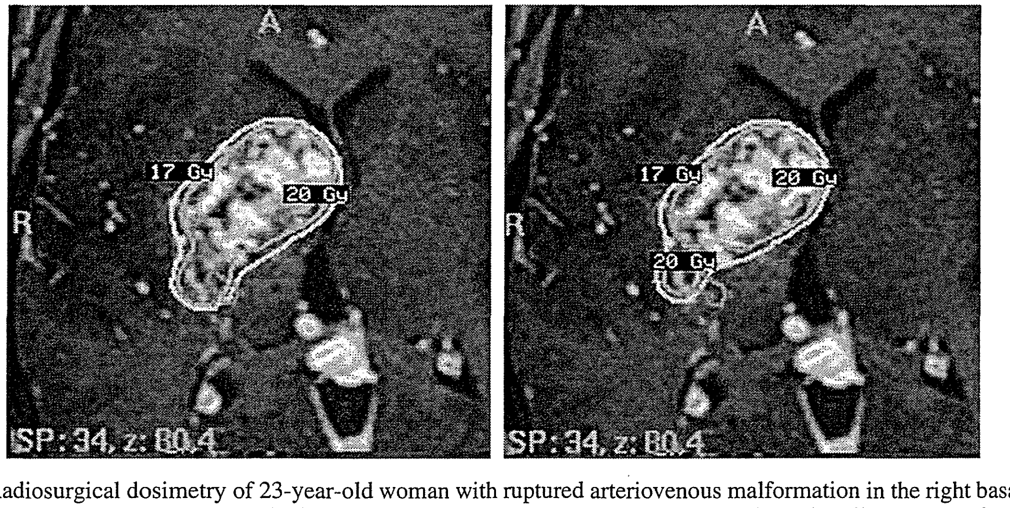

Fig. 1. Radiosurgical dosimetry of 23-year-old woman with ruptured arteriovenous malformation in the right basal ganglia. Dose delivered to the corticospinal tract before referring to tractography (a) was intentionally reduced after its integration (b).

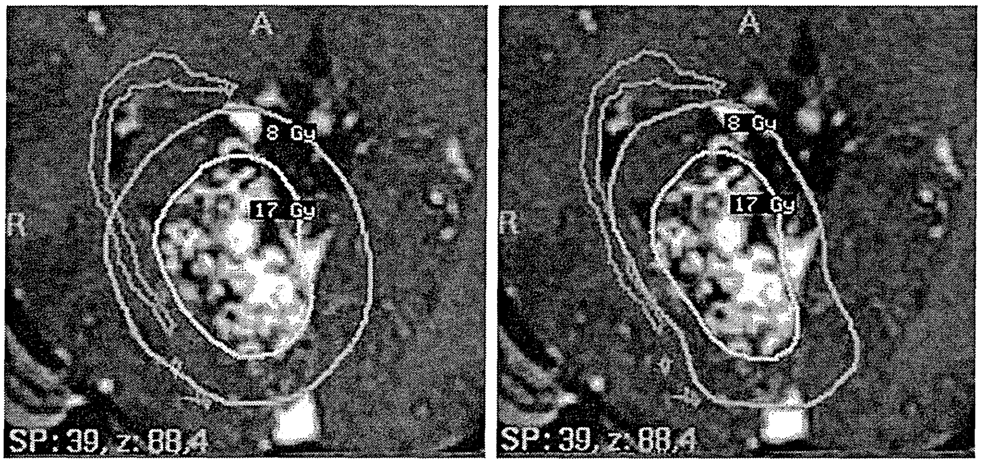

Fig. 2. Radiosurgical dosimetry of 33-year-old woman with unruptured arteriovenous malformation in the right occipital lobe. Dose delivered to the optic radiation before referring to tractography (a) was intentionally reduced after its integration (b).

follow-up at 45 months. This was the only patient who developed permanent morbidity after the prospective integration of tractography. Another patient exhibited mild transient hemiparesis 12 months after treatment prospectively integrating pyramidal tractography but fully recovered after administration of oral corticosteroid agents. Frequency of pre-existing epileptic attacks increased in 3 patients, and new onset of convulsive seizure was observed in 1 patient after radiosurgery. Nidus obliteration was confirmed by magnetic resonance imaging or angiography in 42 patients (29%) until last follow-up. Posttreatment hemorrhage was observed in 2 patients during 319 patient-years. Neither of them exhibited radiation-induced neuropathy before their subsequent hemorrhage. The other patients had no complications throughout the follow-up period.

DISCUSSION

By integrating diffusion tensor tractography of the brain white matter to radiosurgery, permanent and transient morbidity could be reliably prevented in our patients with brain arteriovenous malformations. Although many results of utilizing diffusion tensor–based tractography for diagnostic purposes have been reported (17), its integration into treatment planning of radiosurgery is our original technique and has not been performed at any other institute. Therefore, though this is a retrospective case series, reporting our results would be the most appropriate means to evaluate its efficacy.

Although there are a variety of white matter fiber tracts, we considered that the pyramidal tract would be the most important tract in preventing morbidity of radiosurgery because its injury causes motor paresis and leads to decline of activities of daily living (18, 19). At the same time, the pyramidal tract was practically the easiest one to draw from the technical point of view (17). The optic radiation and the arcuate fasciculus would be next important and are more difficult to draw (20, 21). Injury of the optic radiation causes visual disturbance. Verbal function requires participation of a distributed neural system in the dominant hemisphere, and we integrated the arcuate fasciculus tractography to preserve this function as much as practically possible. For the time being, we are introducing the above three tracts, considering them as critical white matter structures to be preserved. Technical difficulty is also a consideration, as mentioned above. Confirming above three tracts along with anatomically identifiable critical structures of the brain would be sufficient to prevent major disabling morbidity.

Integration of tractography into intraoperative navigation was also developed at our institute (13). However, it contains risks of inevitable brain shift caused by craniotomy or tumor removal, thus leading to poorer accuracy. On the other hand, such a shift does not occur in the setting of integration of tractography into radiosurgery. Therefore, we believe this would be the most suitable clinical application of diffusion tensor tractography in treating brain disorders.

Our study has several potential limitations. Our follow-up period was not long enough to evaluate late adverse events after radiosurgery (6), although it would be appropriate to observe early radiation injury that usually occurs 6 months to 2 years after radiosurgery (2, 6). Longer follow-up would be necessary to investigate whether delayed radiation-induced neuropathy does not affect our result.

Furthermore, the obliteration rate in this study group was low, probably because the median follow-up period of 23 months was shorter than that usually necessary for nidus obliteration, which is 3–5 years (22). One concern is that obliteration on imaging or subsequent prevention of future hemorrhage, which is the therapeutic goal of radiosurgery for arteriovenous malformations, can be compromised by modification of treatment planning by referring to tractography. Therefore, we need to prove, by longer follow-up, that this technique can provide morbidity prevention without lowering the obliteration rate.

Another limitation of tractography is its reliability. There is no guarantee that fibers do not exist where the tracts is not drawn (17, 23). However, tractography has been proven to reflect anatomic pyramidal tract functioning in intraoperative fiber stimulation analysis (24). Therefore, as indicated in this study, irradiation while paying attention to firmly depicted fibers could sufficiently prevent morbidity, and practically this is the best and the only way to prevent morbidity.

The fact that the rate of tractography integration was higher in the last 2 years suggests the feasibility and usefulness of the procedure. We hope our technique will also be applied to future treatment planning software so that even physicians who are unfamiliar with complicated imaging processing can utilize our methodology (10).

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Gynecologic Oncology

journal homepage: www.elsevier.com/locate/ygyno

Changing trend in the patterns of pretreatment diagnostic assessment for patients with cervical cancer in Japan

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article info

Article history:
Received 22 June 2011
Accepted 26 August 2011
Available online 25 September 2011

Keywords:
Cervix
Radiotherapy
Pretreatment examination

abstract

Objective. Cancer staging systems should be responsive to the development of diagnostic tools. The International Federation of Gynecology and Obstetrics (FIGO) cervical cancer guidelines were modi• ed in 2009 regarding the pretreatment assessment. We report the recent Japanese patterns of pretreatment workup for cervical cancer.

Methods. The Japanese Patterns of Care Study (PCS) working group analyzed the pretreatment diagnostic assessment data of 609 patients with cervical cancer treated with de• nitive radiotherapy in the two survey periods (1999• 2001, 324; 2003• 2005, 285) in Japan. Sixty-one of 640 institutions were selected for this survey using a strati• ed two-staged cluster sampling method.

Results. The use of optional examinations in the latest FIGO guidelines such as intravenous urography, cystoscopy, and proctoscopy was gradually decreasing. Surgical staging was rarely performed in either survey period. Computed tomography (CT) and magnetic resonance imaging (MRI) were widely used, and MRI has become increasingly prevalent even between the two survey periods. Primary lesion size and pelvic lymph node status was evaluated by CT/MRI for most patients in both surveys.

Conclusions. The use of CT/MRI that is encouraged in the latest FIGO staging guidelines already replaced intravenous urography, cystoscopy, and proctoscopy in Japan. Japanese patients received the potential bene• t of CT/MRI because prognostic factors such as primary lesion size and pelvic lymph node status were evaluated by these modalities. The use of cystoscopy and proctoscopy should be continuously monitored in the future PCS survey because only CT/MRI could lead to the stage migration for patients on suspicion of bladder/rectum involvement on CT/MRI.

Introduction

Radiation therapy is established as an integral component of cervical cancer. Accurate understanding of the cancer's extent is necessary for appropriate radiation treatment planning. In the • rst place, precise cancer staging is essential to predict prognosis and make appropriate decision regarding the primary treatment. The International Federation of Gynecology and Obstetrics (FIGO) provided a global staging system for gynecologic cancers and made several modi• cations over time. The previous FIGO guidelines recommended that staging be based on physical examination, colposcopy, hysteroscopy, lesion biopsy, cystoscopy, proctoscopy, intravenous urography, and X-ray examination of the chest and skeleton. Of these, • ndings of optional examinations such as lymphangiography, ultrasound, computed tomography (CT), and magnetic resonance imaging (MRI) are of value for planning therapy, but, because these are not generally available and the interpretation of results is variable, the • ndings of such studies should not be the basis for changing the clinical staging [1]. However, cancer staging systems should be based on, and updated according to, the latest available knowledge, implying that they should be responsive and adaptive to scienti• c developments [2]. Thus, the FIGO guidelines for cervical cancer were modi• ed in January 2009. In the updated guidelines, radiological tumor volume and parametrial invasion should be recorded for those institutions with access to MRI/CT [3]. In addition, other investigations such as cystoscopy, proctoscopy, and intravenous urography were classi• ed as optional and no longer mandatory [3].

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0090-8258/$ • see front matter © 2011 Elsevier Inc. All rights reserved.
doi:10.1016/j.ygyno.2011.08.024

The Patterns of Care study (PCS) initially surveyed radiotherapy practice in the United States, and the structure, process, and outcomes of radiotherapy, as well as various problems in clinical practice, have been identi• ed for cervical cancer [4,5]. The Japanese PCS began in 1996 and used the same methods [6]. To accurately evaluate the cancer stage and optimally treat Japanese cervical cancer patients, it is important to accurately delineate the intrinsic changes in the patterns of pretreatment workup for cervical cancer in Japan. We previously reported the care process patterns in pretreatment diagnostic assessment and staging for patients with cervical cancer treated in 1999• 2001 [7]. We report here the corresponding results for 2003• 2005, and the changes over the years in pretreatment work-up from the 1999• 2001 to 2003• 2005 survey periods are examined.

Methods and materials

Between 2006 and 2008, the Japanese PCS conducted a third national survey of patients with uterine cervical cancer treated with radiotherapy. Eligibility criteria for the survey were as follows: (1) carcinoma, (2) treated between January 2003 and December 2005, (3) no distant metastasis, (4) no prior or concurrent malignancy, (5) no gross para-aortic lymph node metastasis, and (6) no previous pelvic radiotherapy. Sixty-one of 640 institutions were selected for this survey using a strati• ed two-staged cluster sampling method. Before the random sampling, all institutions were classi• ed into four groups. Institutions were classi• ed by type and number of patients treated with radiotherapy. The Japanese PCS strati• ed institutions as follows: A1, academic institutions treating • 430 patients annually; A2, b430 patients; B1, nonacademic institutions treating • 130 patients annually; B2, b130 patients. Academic institutions included cancer center hospitals and university hospitals. Nonacademic institutions consisted of other facilities, such as national, prefectural, municipal, and private hospitals. The detailed criteria for strati• cation have been shown elsewhere [6]. The Japanese PCS surveyors performed on-site chart reviews at each participating facility using an originally developed database format for cervical cancer. Data collection included patient characteristics, details of the pretreatment workup, therapeutic information (e.g., radiotherapy, chemotherapy, and surgery), and treatment outcome. The Japanese PCS collected clinical data on 487 patients with uterine cervical cancer who were treated with radiotherapy from 61 institutions. In this study, 285 patients treated by radiotherapy without planned surgery were analyzed. These included 114 patients from A1 institutions, 87 patients from A2 institutions, 50 patients from B1 institutions, and 34 patients from B2 institutions. There were unknown and missing data in the tables because no valid data were found in the given resources.

The current study compared the pretreatment workup data of two Japanese PCS surveys with more than 600 patients (1999• 2001, 324; 2003• 2005, 285) with cervical cancer treated by radiotherapy with curative intent. The methods for the 1999• 2001 Japanese PCS were the same as those for 2003• 2005. Ratios were calculated without unknown or missing data. Statistical signi• cance was tested using the chi-square test.

Results

Table 1 gives a comparison of the patient characteristics between the Japanese PCS 1999• 2001 and 2003• 2005 survey of cervical cancer patients treated with de• nitive radiotherapy. The ages of the analyzed cohort were signi• cantly different in the 1999• 2001 and 2003• 2005 surveys (pb0.0001). Histology and FIGO stage were not signi• cantly different in the two survey periods.

Table 2 shows a comparison of the performance rates of diagnostic procedures with a certain rate of unknown or missing data between the 1999• 2001 and 2003• 2005 surveys. Most patients underwent a chest X-ray in both the 1999• 2001 and 2003• 2005 surveys, but the ratio of patients who underwent a chest X-ray signi• cantly decreased

Table 1
Patient and tumor characteristics of patients with uterine cervical cancer treated with radiotherapy in each surveillance period.

Characteristics	No. of patients (%)		
	1999• 2001 (n = 324)	2003• 2005 (n = 285)	p
Age (years)			b0.0001
Range	26• 100	25• 95	
Median	71	67	
Histology			0.84
Squamous cell	300 (94%)	257 (92%)	
Adenocarcionoma	14 (4%)	14 (5%)	
Adenosquamous cell	4 (1%)	5 (2%)	
Other	2 (1%)	3 (1%)	
Unknown/missing	4 (•)	6 (•)	
FIGO stage			0.13
I	43 (14%)	27 (10%)	
II	102 (34%)	85 (30%)	
III	122 (40%)	132 (46%)	
IVA	35 (12%)	41 (14%)	
Unknown/missing	22 (•)	1 (•)	

Abbreviations: KPS: karnofsky performance status, FIGO: International Federation of Gynecology and Obstetrics.

Table 2
Pretreatment diagnostic procedure in the 1999• 2001 and 2003• 2005 survey periods.

Parameters	No. of patients (%)		
	1999• 2001 (n = 324	2003• 2005 (n = 285)	p
Chest radiography			0.0002
Yes	241 (97%)	191 (88%)	
No	7 (3%)	25 (12%)	
Unknown/missing	76 (•)	69 (•)	
Intravenous urography			b0.0001
Yes	176 (72%)	86 (42%)	
No	68 (28%)	118 (58%)	
Unknown/missing	80 (•)	81 (•)	
Cystoscopy			0.0005
Yes	171 (74%)	123 (58%)	
No	60 (26%)	88 (42%)	
Unknown/missing	93 (•)	74(•)	
Proctoscopy			0.027
Yes	108 (49%)	70 (34%)	
No	114 (51%)	134 (66%)	
Unknown/missing	102 (•)	81 (•)	
Barium enema			0.098
Yes	24 (11%)	14 (7%)	
No	193 (89%)	200 (93%)	
Unknown/missing	107 (•)	71 (•)	
Lymphangiography			0.71
Yes	3 (1%)	16 (9%)	
No	241 (99%)	171 (91%)	
Unknown/missing	80 (•)	98 (•)	
Surgical Staging			0.042
Yes	3 (1%)	10 (4%)	
No	257 (99%)	241 (96%)	
Unknown/missing	64 (•)	34 (•)	
Abdominal CT			0.053
Yes	258 (95%)	247 (98%)	
No	14 (5%)	5 (2%)	
Unknown/missing	52 (•)	33 (•)	
Pelvic CT			0.75
Yes	286 (97%)	255 (98%)	
No	8 (3%)	5 (2%)	
Unknown/missing	30 (•)	25 (•)	
Pelvic MRI			0.021
Yes	246 (86%)	234 (92%)	
No	39 (14%)	19 (8%)	
Unknown/missing	39 (•)	32 (•)	
FDG-PET			0.34
Yes	1 (0%)	0 (0%)	
No	254 (100%)	229 (100%)	
Unknown/missing	69 (•)	56 (•)	

Abbreviations: NA: not applicable.

between the two survey periods. Intravenous urography and cystoscopy were performed in approximately three-quarters of patients in the 1999• 2001 survey, but only half of patients underwent these examinations in the 2003• 2005 survey. The ratio of the patients who underwent proctoscopy also signi• cantly decreased between the two survey periods. On the whole, the ratio of patients who underwent barium enema and lymphangiography was low in both the 1999• 2001 and 2003• 2005 surveys. Surgical staging was rarely performed in either survey. Almost all patients underwent abdominal and pelvic CT in both surveys, and the ratios were not signi• cantly different in the two survey periods. The ratio of the patients who underwent pelvic MRI was already high in the 1999• 2001 survey, but this ratio further increased signi• cantly. The ratio of patients underwent • uorodeoxyglucose positron emission tomography (FDG-PET) was 0% in both the 1999• 2001 and 2003• 2005 surveys.

Table 3 shows the performance status of the pretreatment evaluation for the primary lesion and pelvic lymph nodes with a certain rate of unknown or missing data. Primary lesion size was not evaluated for a certain percentage of patients in both the 1999• 2001 and 2003• 2005 surveys (11% and 15%, respectively). MRI was the most common modality for evaluating primary lesion size in both surveys. Median tumor size in the 2003• 2005 survey was larger than that in the 1999• 2001 survey. Especially, the ratio of tumors N60 mm increased between the two survey periods (13% to 24%). Pelvic nodal status was evaluated in almost all patients in both surveys. CT was most frequently used for the assessment of nodal status in both the 1999• 2001 and 2003• 2005 surveys (86% and 89%, respectively).

Discussion

The present study demonstrated that the use of optional examinations in the updated FIGO guidelines such as intravenous urography, cystoscopy, and proctoscopy is gradually decreasing in Japan, as well as in the United States [4,8,9]. In the 2000• 2002 US study on the pretreatment evaluation of patients with stage IIB or lower disease, the rates for performing intravenous urography, cystoscopy, and proctoscopy were only 1, 16, and 17%, respectively [9]. The National Comprehensive Cancer Network (NCCN) guideline also states that cystoscopy and proctoscopy are optional examinations for the pretreatment assessment of cervical cancer patients with a disease stage of IB2 or higher [10]. On the other hand, this study showed that these optional procedures were still often performed in the patients surveyed in Japan, although these are older data than the FIGO guidelines update. We think that, although cystoscopy and proctoscopy are not necessary for the pretreatment assessment of cervical cancer patients with a disease stage of IB1 or lower, those examinations with biopsy are required for patients with a disease stage of IB2 or higher on suspicion of bladder/rectum involvement on CT or MRI because only CT/MRI could lead to the stage migration. Surgical staging and lymphangiography were rarely performed in either survey period. Eifel et al. reported that lymph node status was assessed by lymphangiography in 13.6%, and surgical evaluation in 12.2%, in the 1996• 1999 US PCS [5], and other studies revealed that the performance of lymphangiography has also been decreasing recently [4,8,9]. Lagasse et al. found lymphangiography to be unreliable as a basis for treatment decisions [11]. As for surgical staging, although the FIGO Committee agrees on its potential important bene• ts, cost-effectiveness is still a matter of investigation and debate in a disease that can be cured with the same ef• cacy by other non-surgical treatment modalities [2]. In addition, there is increased morbidity when surgical node dissection is combined with subsequent radiation therapy [12]. We think that these procedures were replaced by CT or MRI before we started to survey the pretreatment workup data on the Japanese PCS. We predict that the performance rates of intravenous urography, cystoscopy, and proctoscopy will also decrease further, to be replaced by CT or MRI as in the United States. The ratio of patients who underwent a chest X-ray decreased signi• cantly between the two survey periods. We presume that chest X-rays may also be replaced with chest CT, which can be done with abdominal and pelvic CT at one time, although we did not examine the performance status of chest CT in the two surveys.

This study demonstrated that CT and MRI were routinely performed in Japan in both survey periods. In the 1990s, several researchers reported that tumor diameter, as assessed by MRI, signi• cantly affected the outcome of cervical cancer patients treated with de• nitive radiotherapy [13,14]. Actually, the use of diagnostic imaging techniques to assess the size of the primary tumor is encouraged in the updated FIGO guidelines, and radiological tumor volume and parametrial invasion should be recorded for those institutions with access to MRI/CT [3]. This study showed that CT and MRI were already widely used before the revision of the FIGO guidelines in 2009, and pelvic MRI has become increasingly prevalent in Japanese clinical practice for cervical cancer even between the two survey periods. It is clear that the practice patterns of pretreatment workup in Japan and the USA are notable different than in areas which are less well developed. However, there is increasing availability of CT scanning in developing countries [9]. As CT and MRI techniques and training continue to develop, it is likely that accuracy for local staging will improve even further. Thus, we think that these cross-sectional diagnostic imaging will become more and more important to the pretreatment workup of cervical cancer. On the other hand, the use of CT or MRI is encouraged but still is not mandatory in the latest FIGO cervical cancer staging guidelines. As it stands now, it is important to record the staging method for each cervical cancer patient in any countries in order to avoid staging migration and to fairly compare treatment methods.

Primary lesion size was not evaluated for a certain percentage of patients in both surveys. As previously stated, since tumor size is an important prognostic factor for cervical cancer, it is necessary in clinical practice to evaluate the primary lesion size. MRI was the most common modality for evaluating primary lesion size in both surveys. On the other hand, a certain percentage of patients were had primary lesion size

Table 3
Pretreatment evaluation of the primary lesion and lymph node in the 1999• 2001 and 2003• 2005 survey periods.

Parameters	No. of patients (%)		
	1999• 2001 (n = 324)	2003• 2005 (n = 285)	p
Evaluation of primary lesion size			0.30
Yes	246 (89%)	202 (85%)	
No	29 (11%)	36 (15%)	
Evaluation method of primary lesion*			NA
Inspection and palpation	20 (8%)	20 (10%)	
CT	53 (22%)	81 (40%)	
MRI	152 (62%)	145 (72%)	
US	21 (8%)	65 (32%)	
Diameter of primary lesion (mm)			0.008
0• 10	3 (1%)	0	
10• 20	12 (6%)	10 (5%)	
20• 30	33 (15%)	28 (15%)	
30• 40	54 (25%)	25 (14%)	
40• 50	52 (24%)	47 (25%)	
60 b	27 (13%)	45 (24%)	
Unknown/missing	110 (•)	97 (•)	
Median	45 (0• 100)	50 (15• 107)	
Evaluation of pelvic lymph node			0.024
Yes	271 (97%)	224 (90%)	
No	8 (3%)	24 (10%)	
Unknown/missing	45 (•)	37 (•)	
Evaluation method of pelvic lymph node*			NA
CT	233 (86%)	209 (89%)	
MRI	37 (14%)	136 (58%)	
US	0	7 (3%)	
Others	1 (0%)	3 (1%)	

Abbreviations: US: ultrasonography, NA: not applicable.
• Some patients overlap in the 2003• 2005 column.

evaluated by a physician's inspection and palpation, which is the method recommended by FIGO for evaluating primary lesion size. However, we think that tumor size assessment by physical examination has the potential to estimate tumor size incorrectly. Especially in clinical trials, we should evaluate primary lesion size by MRI because of its accuracy. Pelvic lymph node status was not evaluated for a certain percentage of patients in both surveys. Although the evaluation of lymph node status is an important prognostic factor and is essential for radiation treatment planning, it is not included in the FIGO guidelines despite improvements in imaging techniques. We believe that physicians should evaluate the lymph node status at least in institutions with access to MRI/CT because cervical cancer has a poor prognosis in the presence of lymph node metastasis, and this is particularly evident in early stage disease [15]. We think that pelvic CT is unnecessary for the pretreatment assessment of a cervical cancer patient when her MRI covers the whole pelvis, but if not, pelvic CT is also necessary. In addition, abdominal CT is required for the assessment of para-aortic lymph node status in the case of positive pelvic lymph node or a locally-advanced stage.

PET was rarely performed for cervical cancer in the two survey periods in Japan, although it has dramatically increased in the evaluation of patients with malignant neoplasms since approximately 2000 in Japan. This was due to the Japanese health insurance plan which did not cover cervical cancer at that time. Several studies showed the accuracy of PET for the staging of cervical cancer [16]. The Japanese health insurance plan started to cover cervical cancer in 2006. Its application is expected to increase in Japan in the next Japanese PCS survey for cervical cancer.

The limitation of our study was that several cases reviewed in this survey had unknown or missing data. The tables for pretreatment diagnostic tests in this study probably do not provide an accurate estimate of overall usage. Nevertheless, our results demonstrate that the FIGO-recommended workup including cystoscopy and proctoscopy is steadily decreasing in Japan, and there is a large discrepancy between the FIGO-recommended workup with cystoscopy and proctoscopy, and the actual tests being used.

In summary, the Japanese PCS describes the changes over the years in pretreatment work-up from the 1999• 2001 to 2003• 2005 survey periods in Japan. This study revealed that the FIGO recommended workup is steadily decreasing in Japan, while CT and MRI have been routinely performed. Patterns of pretreatment workup should be continuously monitored in order to avoid staging migration, to properly treat individual patients, and to fairly compare treatment methods.

Con• ict of interest statement

None.

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

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

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

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

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

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

Strahlenther Onkol 2011;187:167–74
DOI 10.1007/s00066-010-2205-3

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

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

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Received: August 13, 2010; accepted: October 7, 2010
Published Online: February 21, 2011

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

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

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

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

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

Introduction

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

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

Materials and Methods

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

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

Results

Current Situation of Radiation Oncology

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

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

Tabelle 1. Anzahl neuer Patienten und aller Patienten (neu plus wiedereingeliefert), die der Strahlentherapie bedürfen, in auf Krebsbehandlung spezialisierten Krankenhäusern und anderen Strahlentherapie-Einrichtungen.

	Designated cancer care hospitals	Others	Total
Facilities	349	372	721
New patients	112,101[a]	58,128	170,229[b]
Average no. new patients/facility	321.2	156.3	236.1
Total patients (new + repeat)	135,383[a]	69,704	205,087[b]
Average no. total patients/facility	387.9	187.4	284.4

[a]Since the number of designated cancer care hospitals with RT was 364, the number of new patients in designated cancer care hospitals was estimated at approximately 117,000 (112,101 × 364/349), and the corresponding number of total patients (new plus repeat) at approximately 141,000 (135,383 × 364/349).
[b]Since the number of radiotherapy facilities was 765 in 2007, the number of new patients was estimated at approximately 181,000 (170,229 × 765/721), and the corresponding number of total patients (new plus repeat) at approximately 218,000 (205,087 × 765/721).

patients/facility, the corresponding figures were 387.9 and 187.4, respectively.

Facility and Equipment Patterns and Patient Load/Linac

The radiotherapy equipment patterns and related functions in Japan are shown in Table 2. In DCCHs, 453 linacs and 103 ^{192}Ir RALSs were in current use, while the corresponding data for the other radiotherapy facilities were 354 and 20, respectively. The rate of ownership of equipment at DCCHs was significantly higher than at the other radiotherapy facilities. As for the linac system in DCCHs, the dual-energy function was used in 339 units (74.8%), the three-dimensional conformal radiotherapy (3D-CRT) function in 341 (75.3%), and the IMRT function in 165 (36.4%). For the other radiotherapy facilities, the corresponding figures were 200 (56.5%), 214 (60.5%), and 70 (19.8%). The respective patient load/linac was 296.5 at DCCHs and 175.0 at the other radiotherapy facilities. The distribution of annual patient load/linac in Japan is shown in Figure 1a. The patient load at 20% of DCCHs and 6% of the other radiotherapy hospitals exceeded the JBBG warning level of 400 patients/linac. However, the average patient load/linac at the other facilities was below the guideline level. Compared with the data for 2005 [3], the rate of linac ownership and rate of installation of the various functions (dual-energy, 3DCRT, and IMRT function) in linac increased by 1.7%, 1.7%, 7.8%, and 6.4%, respectively at DCCHs. At the other radiotherapy facilities, these rates increased as well and the corresponding percentages were 1.7%, 0.2%, 7.8%, and 5.9%.

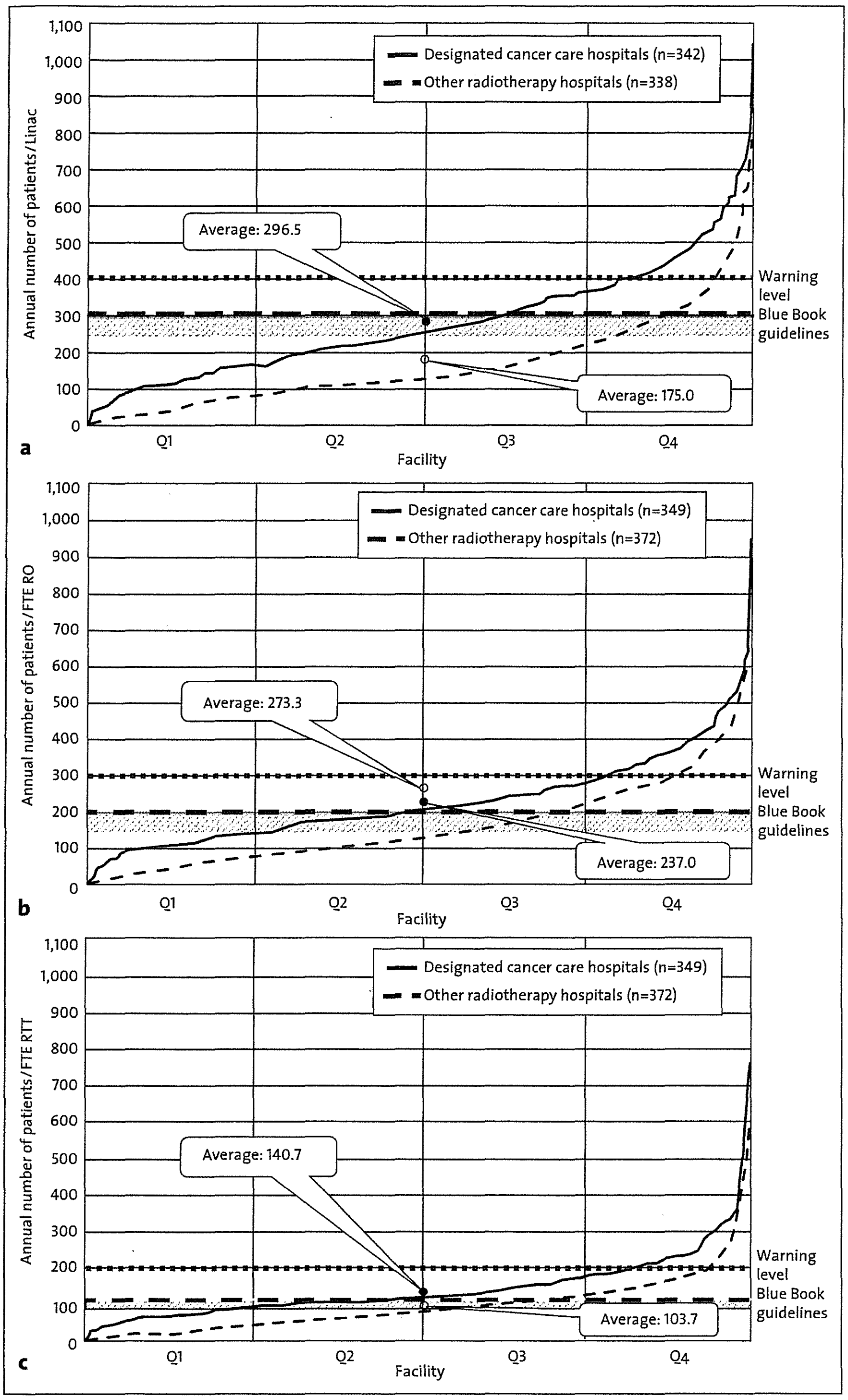
The patterns for radiotherapy planning systems (RTPs) and other equipment are shown in Table 2. X-ray simulators were installed in 69.3% of the DCCHs and in 53.0% of the other radiotherapy facilities, CT simulators in 75.7% and 56.7%, and RTPs in 96.8% and 93.8%, respectively. A noteworthy difference between the two types of facilities was found in the rates of X-ray simulator and CT simulator installation. Compared with the data for 2005 [3], X-ray simulator ownership decreased by 9.8%, while CT simulator and RTP ownership increased by 11.8% and 0.5%, respectively, at DCCHs, while

Table 2. Items of equipment, their function and patient load per unit of equipment in designated cancer care hospitals and other hospitals. Linac: Linear accelerator; IMRT: intensity-modulated radiotherapy; RALS: remote-controlled afterloading system; CT: computed tomography; 3D-CRT: three-dimensional conformal radiotherapy; RTP: radiotherapy planning.

Tabelle 2. Bestrahlungsgeräte, deren Funktion und Patientenaufkommen pro Gerät in auf Krebsbehandlung spezialisierten Krankenhäusern und anderen Strahlentherapie-Einrichtungen. Linac: Linear accelerator; IMRT: intensity-modulated radiotherapy; RALS: remote-controlled afterloading system; CT: computed tomography; 3D-CRT: three-dimensional conformal radiotherapy; RTP: radiotherapy planning.

	Designated cancer care hospitals (n = 349)		Comparison with 2005	Others (n = 372)		Comparison with 2005	Total (n = 721)	
	n	%	%	n	%	%	n	%
Linac	453	98.0[a]	1.7[c]	354	90.9[a]	1.0[c]	807	94.3[a]
with dual energy function	339	74.8[b]	1.7[c]	200	56.5[b]	0.2[c]	539	66.8[b]
with 3D-CRT function (MLC width ≤1.0 cm)	341	75.3[b]	7.8[c]	214	60.5[b]	7.8[c]	555	68.8[b]
with IMRT function	165	36.4[b]	6.4[c]	70	19.8[b]	5.9[c]	235	29.1[b]
Average no. linac/facility	1.3	–	–	1.0	–	–	1.1	–
Annual no. patients/linac	296.5[d]	–	–	175.0[d]	–	–	243.2[d]	–
^{192}Ir RALS (current use)	103	29.5[a]	–	20	5.4[a]	–	127.0	17.1[a]
X-ray simulator	246	69.3[a]	-9.8[c]	199	53.0[a]	-8.7[c]	445	60.9[a]
CT simulator	277	75.1[a]	11.8[c]	220	56.7[a]	8.3[c]	497	65.6[a]
RTP computer	630	96.8[a]	0.5[c]	440	93.8[a]	3.4[c]	1,070	95.3[a]

[a]Percentage of facilities which have this equipment.
[b]Percentage calculated from the number of systems using this function and the total number of linac systems.
[c]Comparison with the data of 2005, calculated with the formula: *data of 2007* (%) – *data of 2005* (%)
[d]Percentage calculated from the number of patients and the number of linac units. The facilities without linac were excluded from the calculation.



Figures 1a to 1c. **a** Distribution of annual patient load/linear accelerator at designated cancer care hospitals and other radiotherapy facilities. Horizontal axis represents facilities arranged in order of increase in annual number of patients/treatment equipment within facilities. **b** Distribution of annual patient load/FTE RO at designated cancer care hospitals and other radiotherapy facilities. Horizontal axis represents facilities arranged in order of increase in annual number of patients/FTE RO within facilities. The number of FTE RO for facilities with FTE <1 was calculated as FTE =1 to avoid overestimating patient load/FTE RO. **c** Distribution of annual patient load/RTT at designated cancer care hospitals and other radiotherapy hospitals. Horizontal axis represents facilities arranged in order of increase in annual number of patients/RTT within facilities. The number of FTE RTT for facilities with FTE <1 was calculated as FTE =1 to avoid overestimating patient load/FTE RTT. Q1: 0–25%; Q2: 26–50%; Q3: 51–75%; Q4: 76–100%.

Abbildungen 1a bis 1c. a) Verteilung des jährlichen Patientenaufkommens pro Linearbeschleuniger in auf Krebsbehandlung spezialisierten Krankenhäusern und anderen Strahlentherapie-Einrichtungen. Die horizontale Achse stellt die Einrichtungen dar, die nach der jährlichen Anzahl der Patienten pro Behandlungsgerät innerhalb der Einrichtungen in aufsteigender Reihenfolge angeordnet wurden. **b)** Verteilung des jährlichen Patientenaufkommens pro Vollzeitäquivalent-Radioonkologe in auf Krebsbehandlung spezialisierten Krankenhäusern und anderen Strahlentherapie-Einrichtungen. Die horizontale Achse stellt die Einrichtungen dar, die in aufsteigender Reihenfolge nach der jährlichen Anzahl der Patienten pro Vollzeitäquivalent-Radioonkologe innerhalb der Einrichtungen angeordnet wurden. Bei Einrichtungen mit Vollzeitäquivalent <1 wurde die Anzahl der Vollzeitäquivalent-Radioonkologen mit Vollzeitäquivalent =1 berechnet, um eine Überschätzung des Patientenaufkommens pro Vollzeitäquivalent-Radioonkologe zu vermeiden. **c)** Verteilung des jährlichen Patientenaufkommens pro Strahlentherapie-MTA in auf Krebsbehandlung spezialisierten Krankenhäusern und anderen Strahlentherapie-Krankenhäusern. Die horizontale Achse stellt die Einrichtungen dar, die in aufsteigender Reihenfolge nach der jährlichen Anzahl der Patienten pro Strahlentherapie-MTA innerhalb der Einrichtungen angeordnet wurden. Bei Einrichtungen mit Vollzeitäquivalent <1 wurde die Anzahl der Vollzeitäquivalent- Strahlentherapie-MTAs mit Vollzeitäquivalent =1 berechnet, um eine Überschätzung des Patientenaufkommens pro Vollzeitäquivalent- Strahlentherapie-MTA zu vermeiden. Q1: 0–25%; Q2: 26–50%; Q3: 51–75%; Q4: 76–100%.

at the other radiotherapy facilities X-ray simulator ownership decreased by 8.7% and CT simulator and RTP ownership increased by 8.3% and 3.4%, respectively.

Staffing Patterns and Patient Loads

Staffing patterns and patient loads in Japan are detailed in Table 3. The total numbers of FTE ROs were 571.3 for DCCHs

Table 3. Structure and personnel of designated cancer care hospitals and other hospitals. RT: radiotherapy; RO: radiation oncologist; FTE: full-time equivalent (40 hours/week only for RT practice); JASTRO: Japanese Society of Therapeutic Radiology and Oncology.

Tabelle 3. Struktur und Personal von auf Krebsbehandlung spezialisierten Krankenhäusern und anderen Strahlentherapie-Einrichtungen. RT: radiotherapy; RO: radiation oncologist; FTE: full-time equivalent (40 hours/week only for RT practice); JASTRO: Japanese Society of Therapeutic Radiology and Oncology.

	Designated cancer care hospitals (n = 349)	Comparison with 2005 (%)	Others (n = 372)	Comparison with 2005 (%)	Total (n = 721)
Facilities with RT bed	171	–	110	–	281 (39.0)
Average no. RT bed/facility	4.3	–	2.0	–	3.1
Total (full + part-time) RO FTE	571.3	21.2[a]	255.0	–15.9[a]	826.3
Average no. FTE ROs/facility	1.6	14.3[a]	0.7	–22.2[a]	1.1
JASTRO-certified RO (full-time)	378	29.0[a]	99	–25.6[a]	477
Average no. JASTRO-certified ROs/facility	1.1	22.2[a]	0.3	–25.0[a]	0.7
Patient load/FTE RO	237.0	–5.8[a]	273.3	14.1[*]	248.2
Total (full + part-time) RT technologist FTE	962.2	–	671.9	–	1634.1
Average no. FTE RT technologists/facility	2.8	–	1.8	–	2.3
Patient load/FTE RT technologist	140.7	–	103.7	–	125.5
Total (full + part-time) medical physicist FTE	42.0	–	26.4	–	68.4
Total (full + part-time) RT nurse FTE	304.3	–	190.1	–	494.4

[a]Rate of increase compared with the data of 2005, calculated with the formula: $\frac{\text{data of 2007 (n)} - \text{data of 2005 (n)}}{\text{data of 2005 (n)}}\ 100\,(\%)$

and 255.0 for the other radiotherapy facilities, while the corresponding average numbers of FTE ROs/facility were 1.6 and 0.7 and the numbers for the patient load/FTE RO 237.0 and 273.3. The distribution of annual patient load/FTE RO in Japan is illustrated in Figure 1b. More than 300 patients/RO (JBBG warning level) were treated in 22% of DCCHs and in 11% of the other facilities. In Figure 2a, the percentage of distribution of facilities by patient load/FTE RO is shown. The largest number of facilities featured a patient/FTE RO level in the 150–199 range for DCCHs and in the 100–149 range for the other radiotherapy facilities. The facilities which have less than 1 FTE RO still account for about 37.2% of DCCHs and 73.9% of the other radiotherapy facilities. In DCCHs, the average numbers of FTE ROs/facility and full-time JASTRO-certified ROs/facility increased by 14.3% and 22.2%, respectively, compared with 2005 data. In other radiotherapy facilities, however, those numbers decreased by 22.2% and 25.0%. The annual patient load/FTE RO decreased by 5.8% in DCCHs and increased by 14.1% in other radiotherapy facilities.

The total numbers of FTE RTTs were 962.2 for DCCHs and 671.9 for the other radiotherapy facilities, and the average numbers per facility were 2.8 and 1.8, respectively. The patient loads/FTE RTT were 140.7 and 103.7, respectively. The distribution of annual patient load/FTE RTT in Japan is shown in Figure 1c. More than 200 patients/RTT (JBBG warning level) were treated in 18% of DCCHs and in 8% of the other radiotherapy facilities, while Figure 2b shows the percentage of distribution of facilities by patient load/FTE RTT. The largest number of facilities featured a patient/FTE RTT level in the 100–119 range for DCCHs and in the 60–89 range for the other radiotherapy facilities. The total numbers of FTE MPs and FTE radiotherapy nurses were 42.0 and 304.3 for DCCHs and 26.4 and 190.1 for the other radiotherapy facilities.

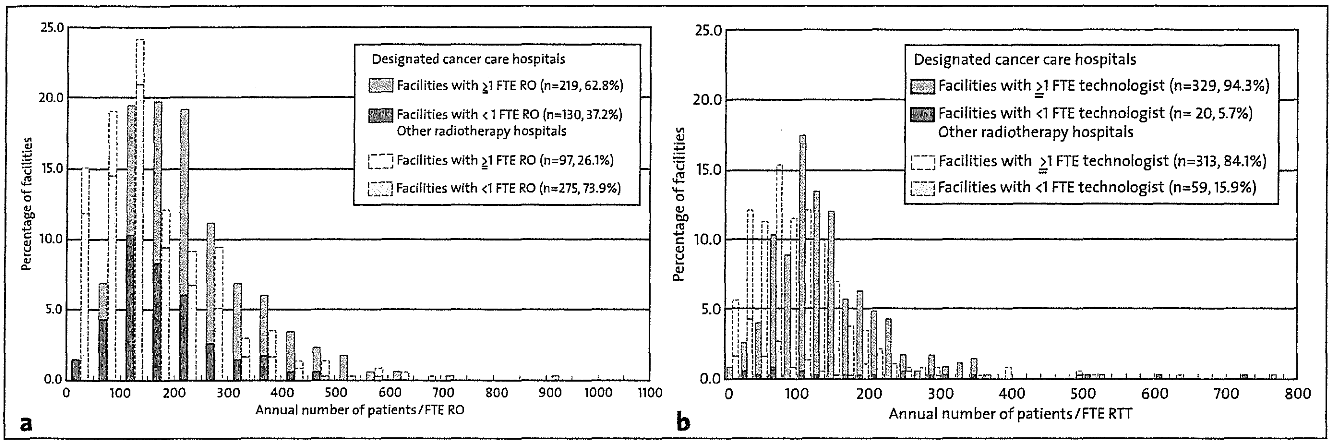
Geographic Patterns

Figure 3 shows the geographic distribution for 47 prefectures of a number of radiotherapy facilities arranged in order of increasing population for all prefectures in Japan [14]. There were significant differences in the average number of facilities per quarter for both all radiotherapy facilities and DCCHs (both: $p<0.0001$). The numbers of all radiotherapy facilities and DCCHs were strongly associated with population size (respective correlation coefficients: 0.95 and 0.82).

Discussion

The utilization rate of radiotherapy for new cancer patients in Japan is less than a half of that for developed countries in Europe, such as France, Germany, Italy, and UK, as well as for the United States. Radiotherapy is expected to play an increasingly important role in Japan because the increase in the elderly population is the highest among developed countries. In Japan, the majority of facilities still rely on part-time ROs, especially in facilities other than DCCHs. The percentage distribution of facilities by patient load/RO in DCCHs proved to be largely similar to that of the United States in 1989 [16]. However, the facilities which have less than one FTE RO still account for about 37% of DCCHs in Japan. In European countries and the United States, on the other hand, most facilities have a full-time RO.

On a regional basis, the results of this study proved that DCCHs were in appropriate locations. In the 2005 survey [9], there were not enough DCCHs in some regions with a large population because many university facilities were not



Figures 2a and 2b. **a** Percentage of facilities by patient load/FTE RO for designated cancer care hospitals and other radiotherapy hospitals. Each bar represents an interval of 50 patients per FTE RO. The number of FTE ROs for facilities with FTE <1 was calculated as FTE =1 to avoid overestimating patient load/FTE RO. **b** Percentage of facilities by patient load/FTE RTT for designated cancer care hospitals and other radiotherapy hospitals. Each bar represents an interval of 20 patients per FTE staff. The number of FTE RTTs for facilities with FTE <1 was calculated as FTE =1 to avoid overestimating patient load/FTE RTT.

Abbildungen 2a und 2b. **a** Prozentsatz der Einrichtungen nach Patientenaufkommen pro Vollzeitäquivalent-Radioonkologe bei auf Krebsbehandlung spezialisierten Krankenhäusern und anderen Strahlentherapie-Krankenhäusern. Jeder Balken stellt ein Intervall von 50 Patienten pro Vollzeitäquivalent-Radioonkologe dar. Bei Einrichtungen mit Vollzeitäquivalent <1 wurde die Anzahl der Vollzeitäquivalent-Radioonkologen mit Vollzeitäquivalent =1 berechnet, um eine Überschätzung des Patientenaufkommens pro Vollzeitäquivalent-Radioonkologe zu vermeiden. **b** Prozentsatz der Einrichtungen nach Patientenaufkommen pro Vollzeitäquivalent-Strahlentherapie-MTA bei auf Krebsbehandlung spezialisierten Krankenhäusern und anderen Strahlentherapie-Krankenhäusern. Jeder Balken stellt ein Intervall von 20 Patienten pro Vollzeitäquivalent-Mitarbeiter dar. Bei Einrichtungen mit Vollzeitäquivalent <1 wurde die Anzahl der Vollzeitäquivalent-Strahlentherapie-MTAs mit Vollzeitäquivalent =1 berechnet, um eine Überschätzung des Patientenaufkommens pro Vollzeitäquivalent-Strahlentherapie-MTA zu vermeiden.

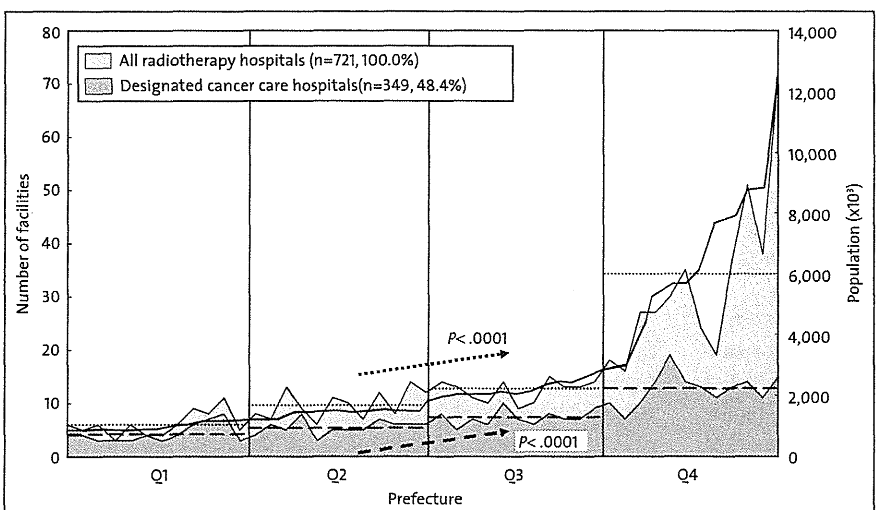


Figure 3. Geographic distribution for 47 prefectures of the number of facilities arranged in order of increase in population. The dotted line shows the average number of facilities of the prefectures per quarter for all radiotherapy hospitals and the dashed line shows the average number for designated cancer care hospitals. Q1: 0–25%; Q2: 26–50%; Q3: 51–75%; Q4: 76–100%.

Abbildung 3. Geografische Verteilung der Anzahl der Einrichtungen in 47 Präfekturen, geordnet in aufsteigender Reihenfolge nach der Bevölkerungszahl. Die gepunktete Linie zeigt die durchschnittliche Anzahl der Einrichtungen der Präfekturen pro Viertel für alle Strahlentherapie-Krankenhäuser, und die gestrichelte Line zeigt die durchschnittliche Anzahl für auf Krebsbehandlung spezialisierte Krankenhäuser. Q1: 0–25%; Q2: 26–50%; Q3: 51–75%; Q4: 76–100%.

certified as DCCHs by the Ministry of Health, Labor, and Welfare. The findings of the current survey show that some university facilities with many patients undergoing radiotherapy were certified as DCCHs. There are, thus, enough radiotherapy facilities in Japan with a nationwide distribution. The medical situation in Japan is susceptible to the effect of measures taken by local governments. Current radiotherapy potential in radiotherapy facilities other than DCCHs in Japan is underutilized because of personnel shortages.

In Japan, a new educational system is being developed to train specialists for cancer care, including ROs, MPs, medical oncologists, oncology nurses, and palliative care doctors. Although the numbers of ROs in DCCHs have increased, the numbers in the other radiotherapy hospitals have decreased. In Japan, many radiotherapy hospitals do not even have their own department of radiotherapy, while we are of the opinion that all radiotherapy hospitals, whether designated or not, need to have

Table 4. Structural features and personnel related to radiation oncology in developed countries and cost adapted from the Directory of Radiotherapy Centers of the International Atomic Energy Agency [4]. RO: radiation oncologist; GDP: Gross Domestic Product.

Tabelle 4. Strukturmerkmale und Personal im Bereich Radioonkologie in entwickelten Ländern und Kosten nach dem Strahlentherapiezentren-Verzeichnis der Internationalen Atomenergie-Organisation [4]. RO: radiation oncologist; GDP: Gross Domestic Product.

Country	RT facilities	ROs	Medical physicists	Population (million)[a]	Facilities/ Population	RO/ Population	Medical physicists/ Population	Medical costs of GDP (%)[b]
Germany	219	835	626	82.7	2.6	10.1	7.6	10.4
Italy	151	839	392	58.2	2.6	14.4	6.7	8.7
France	186	574	267	60.9	3.1	9.4	4.4	11.0
USA	2,514	2,943	1,879	303.9	8.3	9.7	6.2	16.0
Japan[c]	721	826.3[d]	68.4[d]	128.3	5.6	6.4	0.5	8.1

[a]Based on Demographic Yearbook of United Nations [20].
[b]Based on Demographic OECD Health Data 2009 [10].
[c]Based on JASTRO structure survey 2007.
[d]These data are expressed as full-time equivalent. Most ROs or other oncologists at academic facilities work part-time at affiliated hospitals. Therefore, the total numbers of ROs does not reflect the actual structure of radiation oncology personnel in Japan.

their own department of radiotherapy. It was found that MPs work mainly in metropolitan areas or academic facilities, such as university hospitals or cancer centers. At present, there is no national license for MPs in Japan, but those with a master's degree in radiation technology or science and engineering can take the accreditation test for MPs administered by the Japanese Board of Medical Physics (JBMP). The number of RTTs is more satisfactory that that of ROs and MPs, but RTTs are extremely busy because they are also partially act as MPs in Japan. The average number of radiotherapy staff members in DCCHs was greater than that in the other radiotherapy hospitals. Equipment ownership in the other radiotherapy facilities increased compared with 2005, being more firmly established in DCCHs than in the other radiotherapy hospitals. Therefore, the accreditation of DCCHs is closely correlated with the maturity of the radiation oncology structure. Further accreditation of DCCHs by the Ministry of Health, Labor, and Welfare would be a move in the right direction for the geographical consolidation of radiotherapy facilities in Japan.

The Directory of Radiotherapy Centers of the International Atomic Energy Agency has disclosed the member countries' data for the structure of radiation oncology [4]. Table 4 shows the data for the structure of radiation oncology in Japan, Germany, Italy, France, and the United States. The numbers of ROs and MPs per million population in Japan (6.4 and 0.5) are smaller than in France (9.4 and 4.4), Germany (10.1 and 7.6), and Italy (14.4 and 6.7). However, the number of radiotherapy facilities per million population in Japan (5.6) is larger than in France (3.1), Germany (2.6), and Italy (2.6). As for the United States, the numbers of ROs, MPs, and radiotherapy facilities per million population (9.7, 6.2, and 8.3) are all larger than in Japan. These findings do not necessarily mean that the medical care system in Japan is inferior. Even though the medical costs in relation to GDP [10] in Japan are the lowest among the aforementioned five countries, the outcome of cancer treatment in Japan is the same or better than in the other developed countries.

To evaluate medical care systems for cancer at regular intervals, it is very important to collect detailed information for all cancer care facilities. In Japan, JASTRO regularly surveys the structural information for all radiotherapy facilities and PCS has been conducted every 4 years to investigate the processes and outcomes of cancer care using radiotherapy. However, the collection of outcome information is insufficient. In the United States, a National Cancer Data Base was established and has been collecting the data for approximately 75% of cancer patients. This database is used as the quality indicator for improvements in the processes and outcomes of cancer care. We have recently established a Japanese National Cancer Database based on the radiotherapy data, and we are preparing to collect cancer care data with this system.

Conclusion

The structure of radiation oncology in DCCHs in Japan showed more maturity than that of other facilities in terms of equipment, functions, and staff. However, there is still a shortage of manpower. The survey data presented and discussed here are important and fundamental for clearly understanding the medical care system of radiation oncology in Japan. As the survey data make clear, a national policy is needed to solve the problem of the establishment of DCCHs and the shortage of manpower for cancer care.

Acknowledgments

This study was supported by the Japanese Society of Therapeutic Radiology and Oncology and Grants-in-Aid for Cancer Research (Nos. 18–4 and H19–3rd Term Cancer Control–General–038) from the Ministry of Health, Labor and Welfare of Japan and by Grants-in-Aid for Scientific Research from the Japan Society for the Promotion of Sciences (Nos. 19390320 and 20591495). We would like to express our appreciation to all radiation oncologists and radiotherapy technologists throughout Japan who participated in this survey for providing us with valuable information to make this study possible.

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Esophagus (2011) 8:9–29
DOI 10.1007/s10388-011-0266-8

SPECIAL ARTICLE

Comprehensive Registry of Esophageal Cancer in Japan, 2003

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Published online: 24 February 2011

Preface

We are very pleased to publish the Comprehensive Registry of Esophageal Cancer in Japan, 2003, and thank all the members of the Japan Esophageal Society who made great contributions in preparing this material.

We would like to review the history of the registry of esophageal cancer cases in Japan. The Registration Committee for Esophageal Cancer, the Japan Esophageal Society, has annually registered cases of esophageal cancer since 1976 and published the first issue of the Comprehensive Registry of Esophageal Cancer in Japan in 1979. The Act for the Protection of Personal Information was promulgated in 2003, and began to be enforced in 2005. The purpose of this Act is to protect the rights and interests of individuals while taking into consideration the usefulness of personal information, keeping in mind the remarkable increase in the use of personal information arising from the development of today's advanced information and communications society. The registry of esophageal cancer cases has required some adjustments to comply with the Acts. The new registration system has been discussed for several years and was finally completed in 2008. The most important point was

These data were first issued on 1 March, 2011, as the Comprehensive Registry of Esophageal Cancer in Japan, 2003. Not all pages are reprinted here; however, the original table and figure numbers have been kept.
The authors were at the time members of the Registration Committee for Esophageal Cancer, the Japan Esophageal Society, and made great contributions in preparing this material.

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"anonymity in an unlinkable fashion" using encryption with a hash function. Finally, the registry resumed registering cases of esophageal cancer that had been treated in 2001.

In the Comprehensive Registry in 2003, we newly inserted Figure 3: Survival of patients treated by EMR/ESD in relation to the pathological depth of tumor invasion (pT); Figure 4: Survival of patients treated by EMR/ESD in relation to the lymphatic or blood vessel invasion, in order to present the treatment outcome depending on the pathological status.

We briefly summarized the Comprehensive Registry of Esophageal Cancer in Japan, 2003. A total of 4659 cases were registered from 199 institutions in Japan. Comparing the Comprehensive Registry in 2003 to the Comprehensive Registry in 2002, the number of registered cases and surgical cases increased by 378 and 509, respectively, although the number of registered institutions decreased by 23. As for the histologic type of cancer according to biopsy specimens, squamous cell carcinoma and adenocarcinoma accounted for 92.2% and 3.0%, respectively. Regarding clinical results, the 5-year survival rates of patients treated using endoscopic mucosal resection, concurrent chemoradiotherapy, radiotherapy alone, chemotherapy alone, or esophagectomy were 80.0%, 21.9%, 30.3%, 3.0%, and 46.6%, respectively. Concerning the approach used to perform an esophagectomy, 15.5% of the cases were performed endoscopically, that is, thoracoscopically, laparoscopically, or mediastinoscopically. Regarding the reconstruction route, the posterior mediastinal, the retrosternal, and the intrathoracic route were used in 37.3%, 33.3% and 15.7% of cases, respectively. The operative mortality was 1.0% (25 out of 2510 cases).

We hope that this Comprehensive Registry of Esophageal Cancer in Japan for 2003 helps to improve all aspects of the diagnosis and treatment of esophageal cancer.

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I. Clinical factors of esophageal cancer patients treated in 2003

Institution-registered cases in 2003

Institution
Aichi Cancer Center
Aizawa Hospital
Akita University Hospital
Asahikawa Kosei general Hospital
Asahikawa Medical College Hospital

continued

Institution
Chiba Cancer Center
Chiba Prefecture Sawara Hospital
Chiba University Hospital
Dokkyo Medical University Hospital
Foundation for Detection of Early Gastric Carcinoma
Fuchu Hospital
Fujioka General Hospital
Fujita Health University
Fujita Health University Banbuntane Hotokukai Hospital
Gunma Central General Hospital
Gunma University Hospital
Hachinohe City Hospital
Hachioji Digestive Disease Hospital
Hakodate Goryokaku Hospital
Hamamatsu University School of Medicine, University Hospital
Health Insurance Naruto Hospital
Hiratsuka City Hospital
Hiratsuka Kyosai Hospital
Hiroshima City Asa Hospital
Hiroshima University Research Institute for Radiation Biology Medicine
Hofu Institute of Gastroenterology
Hokkaido University Hospital
Hyogo Cancer Center
Hyogo College Of Medicine
Ida Municipal Hospital
Inazawa City Hospital
International University of Health and Welfare Mita Hospital
Ishikawa Kenritsu Chuo Hospital
Ishinomaki Red Cross Hospital
Iwakuni Clinical Center
Iwakuni Medical Center
Iwate Medical University Hospital
JFE Kenpo Kawatetsu Chiba Hospital
Jichi Medical University Hospital
Juntendo University Hospital
Juntendo University Shizuoka Hospital
Kagawa Prefectual Central Hospital
Kagawa University Hospital
Kagoshima Kenritsu Satsunan Hospital
Kagoshima University Hospital
Kanagawa Cancer Center
Kanazawa University Hospital
Kansai Rosai Hospital
Kashima Rosai Hospital
Kashiwa Kousei General Hospital
Kawasaki Medical School Hospital
Keio University Hospital