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Trends for the Past 10 Years and International Comparisons of the Structure of Korean Radiation Oncology

Young Hoon Ji[1,2], Haijo Jung[1], Kwangmo Yang[2], Chul Koo Cho[2], Seong Yul Yoo[2], Hyung Jun Yoo[2], Kum Bae Kim[1,2] and Mi Sook Kim[1,2,*]

[1]Division of Radiation Cancer Research, Research Institute of Radiological and Medical Sciences and [2]Department of Radiation Oncology, Korea Cancer Center Hospital, Korea Institute of Radiological and Medical Sciences, Seoul, Republic of Korea

*For reprints and all correspondence: Mi Sook Kim, Department of Radiation Oncology, Korea Institute of Radiological and Medical Sciences, 215-4 Gongneung-dong, Nowon-gu, Seoul 139-706, Republic of Korea. E-mail: mskim@kcch.re.kr

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Objective: Study aims include determination of nationwide structural characteristics of radiation oncology facilities, types of radiation therapy equipment, availability of human resources and trends and comparisons with previous surveys.
Methods: An annual nationwide survey was conducted to collect the statistics of infrastructure since 1997. All requested questionnaires have been identical for 10 years. The questionnaires included status on basic radiation therapy facilities, human resources and radiation therapy equipment. Journal and statistical data reviews were performed to evaluate the structure of other countries.
Results: Radiation oncology facilities have steadily increased for 10 years and reached 60 sites in 2006. Also a steady increase of 1.5 times for linear accelerators, 5.8 times for computed tomography simulators and 3.0 times for radiation treatment planning systems was noted. Meanwhile, cobalt-60 teletherapy units and hyperthermia equipment had steadily deceased for 10 years. The number of human resources has steadily increased for the past 10 years, especially for radiation therapy technologists. However, radiation therapy equipment and human resources per population are relatively low compared with advanced countries.
Conclusions: This study will assist preparation of the administrative planning policy of radiation oncology and should be useful to indicate the direction of future development and educational training programs in Korea and possibly in other countries.

Key words: radiation oncology – survey – structure – facility – personnel – equipment

INTRODUCTION

Many countries have reported on the status of radiation oncology facilities (1–14). These types of surveys represent useful resources for understanding the infrastructure of radiation oncology in each country. In addition, survey findings are supposed to contribute positively to the development of radiation oncology and administration of facilities.

The Korean Society of Therapeutic Radiology and Oncology (KOSTRO) was established in 1983 and has steadily contributed to the development of radiation oncology in Korea. The Korean Institute of Radiological and Medical Sciences (KIRAMS) has conducted an annual nationwide survey to collect the statistics of infrastructure in radiation oncology for the last two decades since 1990 under the auspices of the KOSTRO. The survey has requested information on annual changes of clinical characteristics (e.g. the number of new patients, treated sites and the number of patients who have received special radiation therapy treatments), facilities, human resources, radiation therapy equipment and other factors for radiation oncology departments on a nationwide basis. Over the past 20 years, the annual results of the surveys have been published periodically in the *Journal of KOSTRO* (14–22). On the basis of these data, in 1997, the infrastructure of radiation oncology facilities in Korea was described and was compared with counterparts in Japan and the USA (16). In addition, changes of clinical characteristics for 10 years from 1997 to 2006 in Korea were reported previously (23).

In this study, we describe changes of structural characteristics of facilities, radiation therapy equipment and human resources over the past 10 years in Korea. Moreover, facilities of different countries were compared with provide information about infrastructure in order to understand the basis of structure of radiation oncology departments worldwide through a review of journal articles.

MATERIALS AND METHODS

Before 2000, survey questionnaires were prepared in a hard copy form and were forwarded by mail annually to the corresponding personnel (primarily, the chief of radiation oncology) in radiation oncology facilities. The completed survey questionnaires were returned by mail. However, from 2001, the website of the department of radiation oncology at the Korea Cancer Center Hospital (KCCH) has included the ability to input annual national statistics from radiation oncology departments. Data were electronically entered through a 'pop-up' box of annual statistics on the website as performed by the designed personnel.

All requested questionnaires over the past 10 years have been identical in the terms of a series of questions. The first questionnaire requested status on basic radiation therapy facilities. The second questionnaire inquired about human resources (the number of radiation oncologists, fellows, residents, medical physicists, dosimetrists, biology researchers and nurses). Human resources were evaluated based on full-time equivalent staffing levels. The third questionnaire asked for information about radiation teletherapy equipment such as external-beam teletherapy equipment [cobalt-60 (Co-60) teletherapy units, medical linear accelerators, CyberKnife units, Tomotherapy units and proton therapy installations], simulators, brachytherapy systems, computer planning systems, radiosurgery systems and conformal systems including multileaf collimator systems. Human resources and radiation therapy equipment such as gamma knife units belong to neurosurgery departments were not included in this study.

In the case of non-responsive facilities, multiple mailings and telephone calls ensured a 100% response from all facilities. Collated data were then reviewed for completeness and logical consistency. There existed slight uncertainties for statistics for radiation therapy equipment with the use of the data collecting method by the use of the website. Follow-up telephone calls were made to clarify inconsistent data or to obtain missing information for requested questions.

We selectively analyzed the characteristics of the facilities and human resources and radiation treatment equipment entered into the computer database from 1997 to 2006 to evaluate trends over the past 10 years. The population statistics were taken from the Korean national statistical office (24). To evaluate the structure of other countries, a journal review was performed.

RESULTS

Facilities and Radiation Therapy Equipment over the Past 10 Years

In 2006, 60 hospitals operated a department of radiation oncology in Korea (the population of Korea was 48 999 × 10^3 in 2006). The number of radiation oncology facilities has steadily increased from 42 sites in 1997 to 60 sites in 2006 as shown in Fig. 1. This finding indicates that the number of facilities per one million of the population for the entire country has increased from 0.90 in 1997 to 1.22 in 2006 (Fig. 1).

There were 100 units of external radiation therapy treatment equipment in 60 facilities: 92 linear accelerators, 1 Co-60 unit, 2 CyberKnife units, 4 Tomotherapy units and 1 proton accelerator in 2006, as shown in Table 1. The number of linear accelerators steadily increased by 1.5 times with an increase in the number of radiation oncology facilities from 61 units in 1997 to 92 units in 2006 as shown in Fig. 2. The number of Co-60 teletherapy units steadily decreased from 10 units in 1996 to 1 unit in 2006. Two microtron units (actually two beam gantries at one accelerator) were dismantled in 2003 and 2006, respectively. This statistics of the microtron units were included and were analyzed with that of the linear accelerators. One CyberKinfe unit and four Tomotherapy units were first introduced to radiation oncology clinics in 2002 and 2006, respectively. The proton accelerator facility was introduced for the first time in 2005. In 2006, two CyberKinfe units, four Tomotherapy units and one proton accelerator were in operation. Co-60 teletherapy units have not been newly installed since 1986, and aging Co-60 teletherapy units have been replaced with new linear accelerators. The number of Co-60 teletherapy units decreased by 90% from 10 units in 1997 to one unit in 2006.

Since 39 conventional fluoroscopy simulators were available in 1997, the number of conventional fluoroscopy

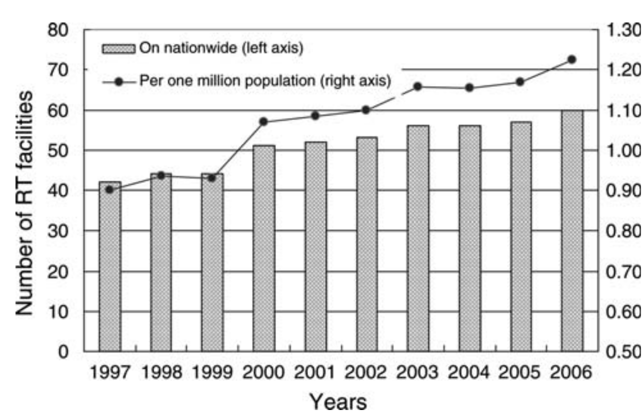

Figure 1. Trends for the number of radiation oncology facilities over the past 10 years in Korea are shown. RT, radiotherapy.

simulators reached a maximum of 57 units in 2004 and gradually decreased to 54 units in 2006. In contrast, the number of computed tomography (CT) simulators steadily increased by 5.8 times from 4 units in 1997 to 23 units in 2006, as shown in Fig. 3. In addition, the number of radiation treatment planning (RTP) systems steadily increased by 3.0 times from 40 in 1997 to 119 in 2006. There were 0.95 RTP systems per facility in 1997 and 1.98 RTP systems per facility in 2006.

The number of high dose rate remote after loading systems (HDR-RALS) was 30 units in 1997 and reached a maximum of 40 units in 2004. There were 39 units at 39 hospitals (65% of all facilities) in 2006, as shown in Fig. 4. The presence of hyperthermia treatment equipment was reported as 11 units at seven hospitals in 1997, but the number of units has steadily decreased to 4 units at four facilities in 2006, as shown in Fig. 4.

Table 1. Trends in radiation oncology facilities and treatment equipment in Korea

Year	1997	2006
Population	$46\ 226 \times 10^3$	$48\ 999 \times 10^3$
Facility number	42	60
Linear accelerators	61	92
CyberKnife units	0	2
Tomotherapy units	0	4
Proton accelerators	0	1
Cobalt-60 units	10	1
X-ray simulators	39	54
CT simulators	4	23
RTP systems	40	119
HDR units	30	39
Hyperthermia units	11	4

CT, computed tomography; RTP, radiation treatment planning; HDR, high dose rate.

Human Resources over the Past 10 Years

There were 131 radiation oncologists including 9 radiation oncology fellows, 49 medical physicists and 365 radiation technologists in 2006, as listed in Table 2. This finding indicates that human resources per facility were 2.03 for radiation oncologists, 0.82 for medical physicists and 6.08 for radiation therapists. Figure 5 shows that the number of employees in radiation oncology facilities steadily increased for all types of employees with the growth of radiation oncology facilities during the past 10 years. There has been an increase of 31% for radiation oncologists. There has been an increase of 81% for medical physicists and 78% for radiotherapy technologists between 1997 and 2006.

DISCUSSION

The number of radiation oncology facilities has gradually increased and the number of radiation oncology facilities per one million of the population has steadily increased as shown in Fig. 1; however, this growth was rapid, particularly after 2000. This trend occurred from effects of an economic recovery in 2002 after the Korean economic crisis in 1998. The number of facilities per one million of the population in Korea was 1.22. Although the surveyed times were different from each other, when compared with France (3.36 in 1999), the USA (5.31 in 1989) and Japan (5.73 in 2005) as developed countries, the number of facilities per one million of the population in Korea is still relatively low (1,10,14).

The increase in the number of linear accelerators was 50.8% from 61 to 92 over the past 10 years from 1997 to 2006. This increase can be compared with a 144.8% increase from 330 in 1990 to 808 in 2005 in Japan and a 28.2%

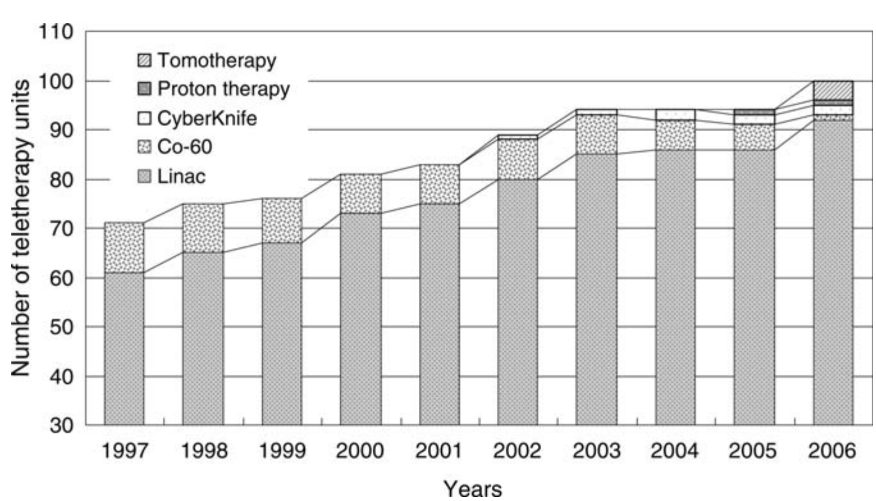

Figure 2. Trends for the number of therapy units (linear accelerators, cobalt-60 units, proton therapy installations, CyberKnife units and Tomotherapy units) in radiation oncology facilities over the past 10 years are shown.

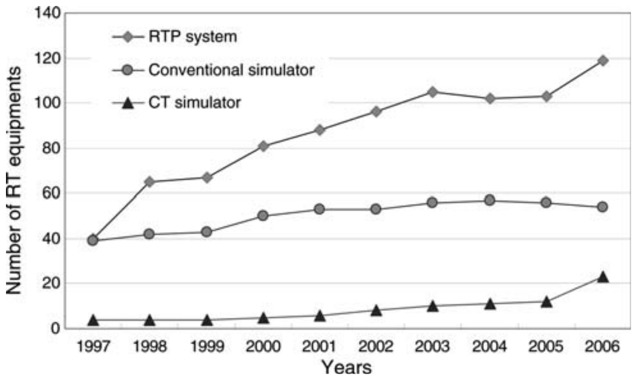

Figure 3. Trends for the number of other specified radiotherapy equipment (RTP systems, conventional simulators, CT simulators) in radiation oncology facilities over the past 10 years are shown. RTP, radiation treatment planning; CT, computed tomography.

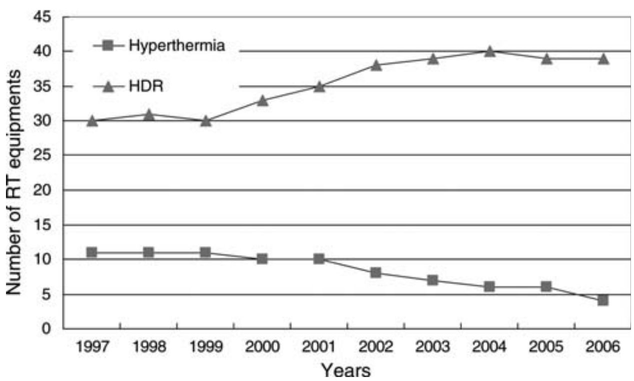

Figure 4. Trends for the number of other specified radiotherapy equipment (hyperthermia and HDR brachytherapy systems) in radiation oncology facilities over the past 10 years are shown. HDR, high dose rate.

Table 2. Human resources in radiation oncology facilities in 2006

Working group	No. of personnel (average no. per facility)
Radiation oncologists	131 (2.18)
Radiation oncology residents	47 (0.78)
Medical physicists	49 (0.82)
Dosimetrists	24 (0.40)
Radiation technologists	365 (6.08)

increase from 1893 in 1989 to 2426 in 1994 in the USA (1,5,11,14). The distribution of megavoltage units per one million of population is listed with data of various counties through a review of journal, as shown in Table 3 (5,7,10,13,14,24, private commutations). The decline of 90.0% in the number of Co-60 units in Korea (from 1997 to 2006) was dramatic and can be compared with a decline of 37.7% in the USA (from 1989 to 1994) or 92.4% in Japan (from 1990 to 2005) (1,5,14). The distribution of Co-60 therapy units for total teletherapy units at radiation oncology facility in various countries is listed in Table 4 (5,8,9,13,14, private commutations). A decreasing trend in Japan was

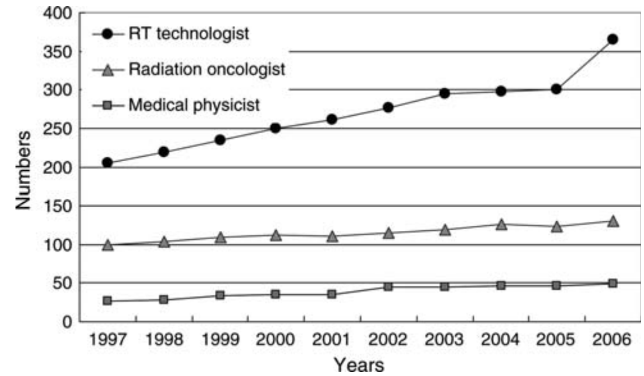

Figure 5. Trends for the number of human resources (radiation oncologists, medical physicists and radiotherapy technologists) in radiation oncology facilities over the past 10 years are shown.

Table 3. The distribution of megavoltage units per one million of the population

Country	Megavoltage units/10^6 population (reference year)
USA	10.55 (1994)
Japan	6.32 (2005)
France	6.08 (1999)
The Netherlands	4.65 (2000)
Germany	4.60 (2000)
Italy	4.31 (2000)
England	3.37 (2000)
Korea	2.04 (2006)
Latin America	1.37 (2000)
China	1.10 (2006)
Bangladesh	0.09 (1999)

Table 4. The distribution of cobalt-60 therapy units for total teletherapy units including at radiation oncology facility in various countries

Country	Cobalt-60 units/total teletherapy units (% ratio)	Reference year
Bangladesh	9/11 (81.8)	1999
Thailand	24/56 (42.9)	2000
China	472/1536 (30.7)	2006
France	87/357 (24.4)	1999
USA	314/2774 (11.3)	1994
Japan	11/808 (1.4)	2005
Korea	1/100 (1.0)	2006

similar to that of Korea. However, data in the case of the USA is not up-to-date.

The number of RTP systems and CT simulators as specified radiotherapy equipment over the past 10 years has rapidly increased in Korea. However, the number of conventional simulators had gradually increased and then decreased in recent years. The total number of RTP systems has rapidly increased by 197.5% for the total number and by

Table 5. Human resource per one million of the population in various countries

Country	Numbers/10^6 population (reference year)		
	Radiation oncologists	Medical physicists	Radiation technologists
USA	10.67 (1994)	5.18 (1994)	27.54 (1994)
Japan	6.04 (2005)	0.92 (2005)	12.79 (2005)
China	4.16 (2006)	0.94 (2006)	3.61 (2006)
Korea	2.67 (2006)	1.00 (2006)	7.45 (2006)
18 countries in Latin America	1.81 (2003)	0.69 (2003)	4.45 (2003)
Thailand	1.08 (2000)	0.63 (2000)	2.10 (2000)

108.2% for the number per facility from 1997 to 2006. This increase is believed to have resulted from an increase in conventional CT and CT simulators according to the required needs for three-dimensional conformal radiotherapy or intensity-modulated image-modified radiation therapy (IMRT).

The number of HDR and hyperthermia units showed a decreasing trend in recent years. The number of HDR-RALS has gradually decreased after 2004 and HDR-RALS were available in 39 hospitals (65% of all 60 facilities) in 2006. The decreasing number of HDRs is thought to be due to the high cost of periodic source exchange, a decline in the incidence of uterine cervix cancer and the application of highly conformal radiation therapy such as IMRT or image-guided radiation therapy in place of previously used HDR procedures. Japan also showed a similar trend where only 34% of the facilities in Japan had HDR units in 1990 (1). The number of patients treated with hyperthermia units has rapidly decreased even though the number of hyperthermia units did not change appreciably. As a decreasing trend in radiation oncology, hyperthermia units were only available in 6.7% of all 60 facilities in 2006. Similarly, this equipment was only available in 2% of all facilities in 2003 in Japan (14). The main reason for the decline of the use of hyperthermia seems to be the inconvenience of application.

The number of human resources has steadily increased for the past 10 years, especially for radiation therapy technologists. However, there have been an insufficient number of medical physicists. Growth in the number of radiation oncologists was more (and less) active from 2001 and this trend is believed to be in accord with the growth of the number of facilities. The number of radiation oncologists per facility in Korea, 2.18, which can be compared with values of 1.80 (USA) in 1994, 1.09 (Japan) in 2005 and 5.51 (China) in 2006 is relatively higher than for the other countries (5,11,13). The number of radiation technologists (6.08 in 2006) per facility seems to be higher than in other countries (5,10,13,14). However, the number of medical physicists per facility was small when compared with that of China and Thailand. If a comparison is made based on per population instead of per facility, the trend could be changed. Human resources per one million of the population in the nation with available information are listed in Table 5 (5,7–9,13,14). In general, the number of human resources (radiation oncologists, medical physicists and technologists) is believed to be definitely lower than that of the USA and Japan. This finding is thought to be related to the relatively lower number of facilities per population. Especially, a notable finding is the number of medical physicists per facility, which had been below one in 2006, and should be improved as medical physicists are usually employed full time in Korea. In Japan, the lack of sufficient number of medical physicist was reported (14). The role of medical physicist is being more emphasized according to the advent of more complicated treatment technologies and instruments. The lack of medical physicists should be improved to provide more accurate and safe radiation treatments.

This type of survey can be useful to understand the status of radiation oncology facilities. In Korea, the number of facilities, linear accelerators and human resources in radiation oncology has steadily increased over the past 10 years. Nevertheless, radiation oncology departments are still immature in infrastructure when compared with international guidelines and radiation oncology facilities are steadily developing. Implementation of new advanced equipment and application of three-dimensional radiation therapy techniques using CT have been actively introduced, and there has been a trend to reduce the number of brachytherapy and hyperthermia units in recent years. However, radiation therapy equipment and human resources per population are low when compared with the USA, Japan and other advanced countries. This study will assist preparation of the administrative planning policy of radiation oncology in Korea and should be useful to indicate the direction of future development and educational training programs in Korea and possibly in other countries.

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Conflict of interest statement

None declared.

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