

## Current Status of the Infrastructure and Characteristics of Radiation Oncology in Korea

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**Background:** An analysis of radiotherapy infrastructure in Korea was performed in 2006 to collect data on treatment devices, the work force and new patients for future development plans.

**Methods:** The survey included radiotherapy centers, their major equipment and personnel. The centers were categorized into four levels: level 0 (stand-alone teletherapy units); level 1 (teletherapy, brachytherapy, treatment planning system, and at least the part-time service of a medical physicist); level 2 (level 1 plus individual customized radiotherapy block and full-time medical physicist); and level 3 [level 2 plus intensity-modulated radiation therapy (IMRT), intra-operative radiation therapy or stereotactic radiotherapy].

**Results:** A total of 61 facilities delivered radiation therapy with 104 megavoltage devices, which included 96 linear accelerators, two cobalt 60 units, three Tomotherapy, two CyberKnife units and one proton accelerator. There were 28 789 new radiotherapy patients in 2004. Personnel included 132 radiation oncologists, 50 radiation oncology residents, 64 physicists, 130 nurses and 369 radiation therapy technologists. Thirty-two percent (20 facilities) used a CT-simulator, 66% (40) used a PET or PET-CT scanner, and 35% (22) had the capacity to implement IMRT. Centers were also divided into four levels: 41% were included in level 3, 31% in level 2, 25% in level 1 and 3% in level 0.

**Conclusions:** There is a shortage of human resources. The distribution of megavoltage units per million inhabitants over the country was inadequate; geographic disparities were noted. Furthermore, the necessity of quality assurance for recent high-technology radiation therapy is increasing.

*Key words: radiotherapy infrastructure of Korea – equipment and facilities – manpower and services*

### INTRODUCTION

Progress in radiotherapy has been rapid, especially in recent years. Radiation oncology in Korea has evolved in both quality and quantity since 2000 and demand for radiotherapy in Korea is steadily increasing. However, there is currently a shortage of human resources, including radiation oncologists and medical physicists. Therefore, there is a need for systematic training of additional personnel. In addition, although almost all institutions are now equipped with

modern radiotherapy facilities, the technical level of services is different for each hospital, and radiotherapy methods including combined treatments are not always uniform. Furthermore, there are geographical disparities within the country. Finally, the importance of quality assurance for current high-technology radiation therapy is increasing.

The Korean Society of Therapeutic Radiology and Oncology (KOSTRO) was established in 1983 and is a growing organization. The KOSTRO has carried out regular structured surveys of Korean radiotherapy for the past 20 years (1–5), surveying the radiation therapy facilities throughout Korea. The survey results are useful and provide an inventory of the current resources, both human resources and radiotherapy equipment, and show the expanding

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patterns of treatment at facilities throughout the country. Based on these data, we can now evaluate the workforce needed in Korea. An analysis of the infrastructure of radiotherapy in Korea was performed in 2006 to collect data on treatment devices, human resources and new patients to establish a baseline plan for future development and to understand the characteristics of current radiation oncology services in Korea.

## MATERIAL AND METHODS

The data from 61 radiotherapy centers was obtained in 2006. The nationwide survey covered radiotherapy centers, major equipment and personnel. A comparative analysis between 2000 and 2006 was performed. Geographical distribution of treatment machines was analyzed. The KOSTRO also surveyed future expansion plans for each department with regard to treatment machines and radiation oncologists.

The centers were categorized into four levels based on the criteria reported by Zubizarreta et al. (6). Level one included teletherapy, brachytherapy, a treatment planning system, immobilization, a radiation oncologist and at least a part-time medical physicist. Level two in addition included simulator imaging, the ability to make individual customized radiotherapy blocks and a full-time medical physicist. Level three also included at least one of the following: an intensity-modulated radiation therapy (IMRT), stereotactic radiotherapy or intra-operative radiotherapy. A department with fewer services than level one, e.g. a stand-alone teletherapy unit, was classified as level 0.

## RESULTS

Sixty-one facilities provided radiation therapy with 104 megavoltage devices. A linear accelerator was the most common form of external irradiation equipment currently used in Korea. Ninety-six linear accelerators, two cobalt 60 units, three Tomotherapy units (Tomotherapy Inc., Madison, WI, USA), two CyberKnife (Accuray, Inc., Sunnyvale, CA, USA) units and one proton accelerator were identified in Korea in 2006. Thirty-five high-dose-rate remote after-loading systems and 20 CT-simulators were also found to be in use. Ten units of a Gamma knife were installed and operated mainly by neurosurgeons. As expected, the number of cobalt teletherapy units had decreased, with a noticeable growth of linear accelerators. A significant number of the linear accelerators (35%) in the past 6 years were additional machines rather than replacements. Cobalt teletherapy machines had been replaced by linear accelerators, and high-precision radiotherapy systems including Tomotherapy, CyberKnife, three-dimensional conformal radiotherapy (3DCRT) and IMRT systems have been introduced during the last 6 years. Table 1 shows the changes in radiotherapy infrastructure. According to the future expansion plans from

each department, the number of megavoltage units is expected to be 139 (45% increase) within 5 years.

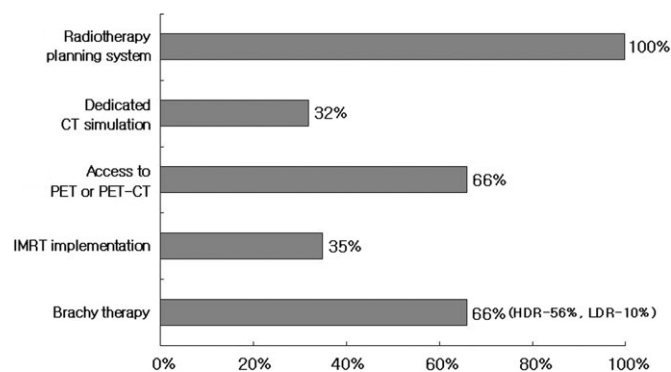
The centers were also divided into four technical levels according to the criteria reported by Zubizarreta et al. (6): 41% (25 facilities) were level 3, 31% (19 facilities) level 2, 25% (15 facilities) level 1 and 3% (two facilities) level 0. All of the facilities employed treatment-planning computers and simulators. Current treatment planning is carried out mainly by treatment planning CT. Thirty-two percent (20 facilities) used a dedicated CT-simulator, 66% (40 facilities) a PET or PET-CT scanner and 35% (22 facilities) had the capacity to implement IMRT. The percentages of centers with cutting-edge techniques or technologies during the survey are presented in Fig. 1.

There were 28 789 new radiotherapy patients in 2004, compared with 21 345 in 2000. Personnel included 132 radiation oncologists, 50 radiation oncology residents, 64 medical physicists, 130 nurses and 369 radiation therapy technologists. As noted in Table 1, the number of radiation oncologists increased by 18% from 2002 to 2006. This was equivalent to the increase (13.5%) in the number of patients irradiated in 2004 compared with 2000. A remarkable growth was observed in health care workers who provide radiotherapy, including radiotherapy technologists, nurses and radiation oncology residents. Among these, the increase in the number of radiation oncology residents is especially notable. According to the future expansion plans for each department, the number of radiation oncologists is expected to be 192 within 5 years (45% increase).

**Table 1.** Recent trends in radiation oncology infrastructure and human resources in Korea: 2006 compared with 2002 inventory

	2000	2006	Increase (%)
Radiotherapy facility	51	61	10 (20)
Human resources			
Radiation oncologists	112	132	20 (18)
Radiation oncology residents	15	50	35 (233)
Medical physicist and dosimetrists	46	64	18 (39)
Radiotherapy technologists	250	369	119 (47)
Nurses	84	130	46 (55)
Total manpower	507	745	238 (47)
Treatment machines			
Linear accelerators	71	96	25 (35)
Proton accelerator		1	
Cobalt 60 teletherapy	8	2	-6 (-75)
CyberKnife		2	
CT-simulator	5	20	15 (300)
Tomotherapy		3	
Gamma Knife	5	10	5 (100)

CT, computed tomography.



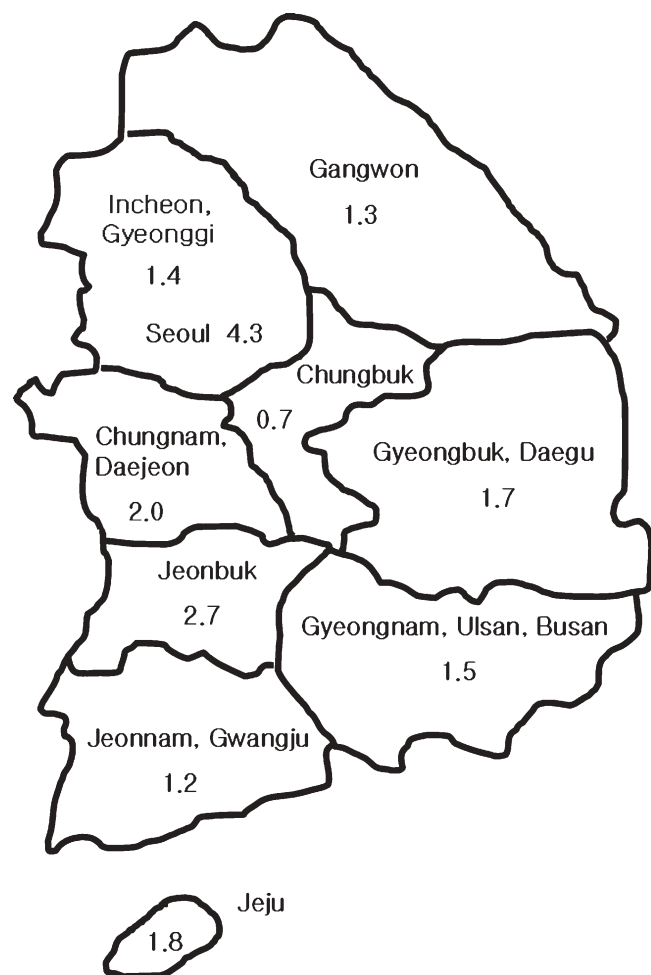
**Figure 1.** Radiation oncology technology available in Korea 2006. Use of a dedicated CT-simulator and PET or PET-CT scanner is increasing. The number of centers employing high-dose-rate (HDR) brachytherapy is increasing while the use of low-dose-rate (LDR) has decreased. IMRT, intensity-modulated radiation therapy; CT, computed tomography; PET, positron emission tomography.

In Korea, the ratio of megavoltage machines to the population is 2.1 per million. This ratio is expected to be 2.8 within 5 years. The distribution of facilities and megavoltage units over the country was adequate for metropolitan areas (4.3 megavoltage unit per one million); however some geographical disparities were noted in the country. The minimum megavoltage per million was 0.7 in Chungbuk province (Fig. 2).

## DISCUSSION

Between 2000 and 2006, significant growth (47%) was observed in human resources, including radiation oncologists, radiation oncology residents, medical physicists, radiotherapy technologists and nurses. Among them, increase in the number of radiation oncology residents has been especially notable. The number of radiation oncology facilities grew by 20% (Table 1). Demand for radiotherapy in Korea is increasing steadily. However, only 26% of cancer patients in Korea undergo radiotherapy, which is a very low proportion compared with 60% in the USA (5, 7). There is some evidence that the known increase in cancer incidence in an aging population and changes in disease management are also leading to an increased demand for radiotherapy. With regard to radiation therapy equipment, a significant proportion (35%) of the new linear accelerators that have been commissioned over the past 5 years have been additional machines. There is a rapid transition from cobalt 60 teletherapy units to high-energy linear accelerators and other accelerators, including proton therapy, CyberKnife and Tomotherapy (Table 1). In the last six years, the installation of dedicated CT-simulator and PET or PET-CT in many clinics has promoted the application of 3DCRT and IMRT for a variety of cancers.

At present, there are 61 institutions with radiation oncology facilities. Since 2000 radiation oncology in Korea has



**Figure 2.** Megavoltage radiotherapy units per million people in Korea for each region in 2006.

been rapidly evolving in both quality and quantity. However, the system for training specialists has been inadequate. As a result, there has been a relative shortage of radiation oncologists and medical physicists. There is a clear need for an improved training system. In 2004, the KOSTRO increased the required number of radiation oncologists for resident training. Each department can accept one less resident each year than the number of radiation oncologists. Therefore, at least two radiation oncologists are required to have a resident in the department each year. Also, to improve the training quality, the KOSTRO conducts an annual written examination session during the spring KOSTRO meeting. All residents are required to take teaching courses as well as an examination during the KOSTRO meeting.

At present, there are 132 working KOSTRO-certified radiation oncologists, 50 residents in training and 64 medical physicists, as well as 369 radiation therapy technologists dedicated to the field of radiation oncology. Although the annual number of cancer patients treated per one radiation oncologist was 227 in Korea in 2004, significant disparities exist among institutions (5). The radiation oncologists at the

larger institutions treat more patients. The annual fresh new patient load per one radiation oncologist in the top 10 hospitals, according to the number of radiation therapy patients, is 341, which is 58% higher than the average number (215) at other institutions. In order to increase the treatment quality, overloading in the top 10 hospital is undesirable. Instead, the large percentage of cancer patients living in provinces needs to be treated in regional medical centers. Therefore, referrals to regional hospitals will be necessary. According to the 'Blue Book' US guidelines and patterns of care study 1999–2001 data in Japan, treatment of 200 patients per year by one radiation oncologist is regarded as standard; treatment of 300 or more patients per year can lead to a decline in the quality of care and increases in numbers staff should be considered (warning level) (8–10). Understaffing of radiation oncologists is at the warning level at the top 10 institutions, which account for half of all the radiation therapy patients. Nationwide recruitment and education of radiation oncologists as well as medical physicists are essential. In particular, recent advances in radiotherapy technologies such as 3DCRT, IMRT and image-guided radiotherapy require large numbers of such personnel. The annual number of cancer patients treated per radiation therapy technologist was 78. This was apparently adequate, as treatment of 120 patients by one radiation therapy technologist per year is regarded as standard (7–9). Furthermore, the patient number per megavoltage device was 323 in 2004. Large discrepancies were noted when comparing the Korean data with data from the USA in 1994 and Japan in 2003 (11, 12).

Comparison of linear accelerator provision in Korea with that in other countries confirms that Korea still lags behind most of the Organization for Economic Cooperation and Development (OECD) countries. In Korea, the ratio of megavoltage machines to the population is 2.1 per million. It is planned to change this ratio to 2.8 within 5 years. The distribution of facilities and megavoltage units per million inhabitants over the country was adequate in metropolitan areas (4.3 megavoltage unit per one million). However, some geographical disparities in the country were noted. According to recent reports, the provision of linear accelerators per million population was 3.37 in the UK, 4.64 in the Netherlands, 6.12 in France, 4.60 in Germany and 6.7 in Japan in 2003 (12, 13). According to the OECD Health Data 2006 report, total health spending accounted for 5.6% of gross domestic product (GDP) in Korea in 2004 (14). Health spending as a share of GDP in Korea is the lowest among OECD countries. However, the share of public investment in health in Korea has steadily increased during the past decade. Expansion of radiation therapy equipment as well as the establishment of regional cancer centers is currently underway. Since 2006, the Ministry of Health and Welfare (MOHW) has conducted a 10 year project to decrease mortality from cancer. It includes founding a regional cancer center in each province. As a result, nine national university medical institutes located in nine provinces have been supported to establish cancer centers, funded by the local

municipal authority as well as MOHW. The regional cancer centers will increase the early detection rate, provide high-quality treatment and develop diverse research in cancer-related subjects. Also cancer management programs such as prevention, education and statistics of cancer have been implemented. The national regional cancer center plan with substantial new investment in radiotherapy equipment will help to improve the infrastructure of radiotherapy in Korea in the near future. According to the future expansion plan survey from each department, the number of radiation oncologists is expected to be 192 (45% increase) and the number of megavoltage units is expected to be 139 (45% increase) within 5 years. It is predicted that 40 000 patients will be treated with radiation in 2010 and about 50 000 in 2015 (5). We estimate that expanded numbers of 167 megavoltage units (assuming 300 radiation patients annually per unit), 250 radiation oncologists (assuming 200 patients annually per physician), 125 medical physicists (assuming 400 patients annually per physicist) and 625 radiotherapy technologists (assuming 80 patients per technologist) will be required for the predicted annual number of patients in 2015 of 50 000.

In conclusion, the facilities survey continues to provide a useful source of census data on radiation oncology in Korea. This information is important for planning future development of equipment installation and training programs. The main problem in the field of radiation oncology in Korea is the shortage of human resources, including radiation oncologists and medical physicists. In addition, the distribution of facilities and megavoltage units per million inhabitants over the country was inadequate and geographical disparities were noted. Close networking and referral systems between the major hospitals in the metropolitan areas and provincial medical centers should be developed. Furthermore, it is of urgent importance to create and maintain a system that can monitor the quality of radiotherapy for public reassurance.

#### Conflict of interest statement

None declared.

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