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On-site audits to investigate the quality of radiation physics of radiation therapy institutions in the Republic of Korea

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ABSTRACT

Purpose: To investigate and improve the domestic standard of radiation therapy in the Republic of Korea.
Methods: On-site audits were performed for 13 institutions in the Republic of Korea. Six items were investigated by on-site visits of each radiation therapy institution, including collimator, gantry, and couch rotation isocenter check; coincidence between light and radiation fields; photon beam flatness and symmetry; electron beam flatness and symmetry; physical wedge transmission factors; and photon beam and electron beam outputs.
Results: The average deviations of mechanical collimator, gantry, and couch rotation isocenter were less than 1 mm. Those of radiation isocenter were also less than 1 mm. The average difference between light and radiation fields was 0.9 ± 0.6 mm for the field size of 20 cm × 20 cm. The average values of flatness and symmetry of the photon beams were 2.9% ± 0.6% and 1.1% ± 0.7%, respectively. Those of electron beams were 2.5% ± 0.7% and 0.6% ± 1.0%, respectively. Every institutions showed wedge transmission factor deviations less than 2% except one institution. The output deviations of both photon and electron beams were less than ±3% for every institution.
Conclusions: Through the on-site audit program, we could effectively detect an inappropriately operating linacs and provide some recommendations. The standard of radiation therapy in Korea is expected to improve through such on-site audits.

1. Introduction

Radiation therapy has an important role in the treatment of malignant diseases, together with surgery and chemotherapy [1,2]. Around the world, approximately 40% of cancer patients currently require radiation therapy, and this number still increases [3]. For a successive and safe application of radiation therapy, prescribed doses should be delivered to patients accurately and precisely because radiation could damage not only tumor cells but also normal tissues [4–6]. Therefore, a variety of guidelines and recommendations on quality control of radiotherapy procedures have been suggested by international organizations such as International Atomic Energy Agency (IAEA) or American Association of Physicists in Medicine (AAPM) [7–13]. Although these guidelines are believed to be properly followed by adequately trained professionals in most clinics, it has been reported that worldwide approximately 10% of patients received radiotherapy were either overexposed or underexposed [14]. This was known to be caused by a lack of proper equipment, personal skill, and training of personnel. Therefore, standardization of radiation therapy quality across clinics seems essential for common good. There have been attempts of audit programs to standardize and to verify the quality of radiation therapy [15–22]. The audit program is also functional in establishing greater confidence in practice of the local radiotherapy institutions, in which quality assurance (QA) programs are generally performed by a single medical physicist [16,20].

Audit programs can be categorized by two types: a postal audit program and an on-site audit program. The Imaging and Radiation Oncology Core (IROC) at MD Anderson Cancer Center (former Radiologic Physics Center, RPC) performs both postal and on-site audit programs for the institutions participating in the clinical trial of Radiation Therapy Oncology Group (RTOG) [23]. Ferreira et al. reported the postal audit results obtained by European Society

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for Therapeutic Radiology and Oncology (ESTRO) QA Network in Germany [15]. They checked photon beams as well as electron beams with thermo-luminescent dosimeters, and 2% of the examined beam outputs showed deviations larger than 5% than those stated by the institutions [15]. Mizuno et al. also reported postal audit results performed for clinical trials in Asia [19]. They checked output constancy over 11 countries with radiophotoluminescent glass dosimeters and reported that a single beam out of 46 tested beams showed an output deviation larger than 5% [19]. Hurkmans et al. also reported the international multicenter beam output results of a postal audit program of European Organization for Research and Treatment of Cancer (EORTC) Radiation Oncology Group [17]. A total of 3151 beams including both photon and electron beams were tested, and 13 beams showed output deviations larger than 5% in their study [17]. On the other hand, Hourdakis and Boziari reported the on-site audit results of every radiation therapy institution in Greece [16]. They reported that 31% of the tested cobalt machines and 7% of the tested linacs showed output deviations larger than 5% [16]. Muhammad et al. reported on-site audit results of 22 radiation therapy institutions in Pakistan, and they reported that 4.4% of the tested beams showed deviations larger than 5% [20].

In the Republic of Korea, approximately 30% of cancer patients receive radiation therapy, and both their relative and absolute numbers currently increase [24]. For the purpose of national welfare improvement as well as common good, an on-site audit program has been recently initiated by the Korean government, Nuclear Safety and Security Commission, and Korea Institute of Nuclear Safety. The schedule of visit and items of the on-site audit were informed to the object institution in advance to provide enough time to prepare for the on-site audit. The on-site audit program included some mechanical and dosimetric checks for radiotherapy machines based on the AAPM guidelines for linac QA [7,8,10]. Currently, 13 institutions out of 90 institutions in the Republic of Korea participated in this on-site audit program from December 2015 to December 2016, and the results are reported in this study.

2. Materials and methods

2.1. Selection of object institutions and on-site audit procedure

Thirteen radiotherapy institutions located in major cities out of 90 institutions in the Republic of Korea (14.4%) were selected for this on-site audit program. Three institutions were examined in December 2015, while 10 institutions were examined in 2016. Most institutions participating in this on-site audit program had multiple linacs, however, a single linac per institution was examined. Among the 13 tested linacs, four machines were manufactured by Elekta, which were one Infinity and three Synergy platforms (Elekta AB, Stockholm, Sweden), while nine machines were manufactured by Varian Medical Systems, which were one TrueBeam STx, two Novalis Tx, two Clinac 21EX, and four Clinac iX (Varian Medical Systems, Palo Alto, CA, USA).

For the on-site audit program, a medical physics expert group was organized to include six physicists whose institutions are currently participating in the international audit programs such as IROC audit program. From the six physicists in the expert group, three physicists visited an object institution together to perform the on-site audit program. The schedule of visit and items of the on-site audit were informed to the object institution in advance to provide enough time to prepare for the on-site audit. The equipment for the on-site audit program was prepared by the expert group, and the equipment of the object institution was not used. All equipment, including ionization chamber, electrometer, thermometer, and barometer were appropriately calibrated and examined before each on-site audit. The ionization chamber with electrometer were calibrated at the Secondary Standards Dosimetry Laboratory (SSDL). The thermometer and barometer were calibrated at the manufacturer. During on-site audit, some mechanical and dosimetric checks were carried out with this equipment, and the QA procedure of the object institution was reviewed by the expert group and discussed with the on-site physicist together. Some institutions had 6 MV and 10 MV photon beams while other institutions had 6 MV and 15 MV photon beams. Therefore, for dosimetric checks, 6 MV photon beams were investigated since every institution had 6 MV photon beams. For electron dosimetric checks, we chose 9 MeV electron beams.

2.2. Items of the on-site audit program

The items of the on-site audit program in this study were based on the AAPM Task Group (TG) 40 and 45 reports [7,8,10]. Although the most recent protocol for linac QA is the AAPM TG-142, items of the on-site audit were based on the AAPM TG-40 and 45 since some institutions did not perform intensity modulated radiation therapy or stereotactic ablative radiotherapy [11]. The items included mechanical collimator, gantry, and couch rotation isocenter tests as well as radiation collimator, gantry, and couch rotation isocenter tests, which were described in the AAPM TG-40 protocol [10]. The mechanical gantry rotation isocenter was checked by using two surrogate references for the isocenter [10]. One was attached to the couch pointing the isocenter horizontally, and another was attached to the gantry mount pointing the isocenter. During a full rotation of the gantry, relative movements of the surrogate reference for the isocenter attached to the gantry mount to the fixed surrogate reference for the isocenter attached to the couch were observed. The mechanical collimator and the couch rotation isocenter were checked by observing the movements of the crosshair center during a full collimator rotation and a full couch rotation, respectively, using a graph paper. The radiation gantry, collimator, and couch rotation isocenter were checked using a spoke shot with solid water phantoms and radiochromic films (EBT3, Ashland Inc., Covington, KY, USA) using 6 MV photon beams. The results of the spoke shot for checking radiation collimator, gantry, and couch rotation isocenter were analyzed with the RIT 113 software (Radiological Imaging Technology, Colorado Springs, CO, USA).

The items also included the coincidence between light and radiation fields (field coincidence test) with photon beams by using EBT3 films and solid water phantoms. The field size, source to axis distance, and the depth of the EBT3 film location were 20 cm × 20 cm, 100 cm, and the depth of the dose maximum (d_{max}), respectively. To minimize the penumbrae, 6 MV photon beams, *i.e.* the photon beams of the lowest energy, were used for the field coincidence test.

The flatness and symmetry of the 6 MV photon beam profiles as well as those of 9 MeV electron beams were checked with solid water phantoms and the EBT3 films [10]. Since a single institution did not commission electron beams, 12 flatness and 12 symmetry tests were performed for the electron beams, while 13 tests were performed for the photon beams. The flatness and symmetry were calculated according to the definitions described in AAPM TG-45 [7].

The physical wedge transmission factors (WFs) were measured by acquiring the ratio of the output of the wedged field to the output of the open field by using 6 MV photon beams with a field size of 10 cm × 10 cm at the reference depth of each institution. For the Varian linacs, WF values of 15°, 30°, 45°, and 60° wedges were acquired. For the Elekta linacs, the WF value of the 60° universal wedge was acquired. Since measurements of the WFs were

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