Radiotherapy and Oncology 81 (2006) 158—162
www.thegreenjournal.com

Head and neck IMRT

Influence of intravenous contrast agent on dose calculations of intensity modulated radiation therapy plans for head and neck cancer

Youngmin Choi[a,*], Jeung-Kee Kim[a], Hyung-Sik Lee[a], Won-Joo Hur[a], Young-Seoub Hong[b], Sungkwang Park[c], Kijung Ahn[c], Heunglae Cho[c]

[a]*Department of Radiation Oncology, and* [b]*Department of Preventive Medicine, College of Medicine, Dong-A University Hospital, Sugu, Busan, South Korea,* [c]*Department of Radiation Oncology, College of Medicine, Inje University, Busan, South Korea*

Abstract

***Background and purpose*: To evaluate the effect of an intravenous contrast agent (CA) on dose calculations and its clinical significance in intensity modulated radiation therapy (IMRT) plans for head and neck cancer.**

***Materials and methods*: Fifteen patients with head and neck cancer and involved neck nodes were enrolled. Each patient took two sets of computerized tomography (CT) in the same position before and after intravenous CA injections. Target volumes and organs at risk (OAR) were contoured on the enhanced CT, and then an IMRT plan of nine equiangular beams with a 6 MV X-ray was created. After the fusion of non-enhanced and enhanced CTs, the contours and the IMRT plan created from the enhanced CT were copied and placed to the non-enhanced CT. Doses were calculated again from the non-enhanced CT by the same IMRT plan. The radiation doses calculated from the two sets of CTs were compared with regard to planning target volumes (PTV) and the three OARs, both parotid glands and the spinal cord, by Wilcoxon's signed rank test.**

***Results*: The doses (maximum, mean, and the dose of 95% of PTV received ($D_{95\%}$)) of PTV70 and PTV59.4 calculated from the enhanced CTs were lower than those from the non-enhanced CTs ($p < 0.05$), but the dose differences were less than 1% compared to the doses calculated from the enhanced CTs. The doses of PTV50.4, parotid glands, and spinal cord were not significantly different between the non-enhanced and enhanced CTs.**

***Conclusions*: The difference between the doses calculated from the CTs with and without CA enhancement was tolerably small, therefore using intravenous CA could be recommended for the planning CT of head and neck IMRT.**
 Radiotherapy and Oncology 81 (2006) 158—162.

Keywords: Contrast agent; Dose calculation; Intensity modulated radiation therapy; Head and neck cancer

Intensity modulated radiotherapy (IMRT) is most commonly used for genitourinary, head and neck, and central nervous system tumors [16]. The head and neck region is considered an ideal target for IMRT for several reasons [17]. First, IMRT offers the potential for improved tumor control through delivery of high doses to the target volume. Second, because of sharp dose gradients, IMRT results in the relative sparing of normal structures. Third, organ motion is virtually absent, so, with proper immobilization, treatment can be delivered accurately. However, the anatomy of the head and neck region is complex, and many tumor targets are in tight proximity to the organs at risk (OAR). Accurate contouring of the target volumes and OARs is prerequisite in order to get a high degree of dose conformity in IMRT. Therefore, an intravenous contrast agent (CA) is helpful in delineating the tumor targets and OARs in computerized tomography (CT). Some authors have suggested that the administration of an intravenous CA is essential for planning CTs [4,6,21].

In a volume-based radiotherapy planning system like three-dimensional conformal radiotherapy or IMRT, CT images are used for the creation of three-dimensional graphics and Hounsfield units (HU) of CT numbers are used as the basis for dose calculation and heterogeneity correction. Iodine containing CAs, used during CT imaging, lead to an increase of HU in tissues with increased CA uptake, and the high HU acts like high density tissue for dose calculation [20]. But, the CA is only present during the CT acquisition process, not during treatment. Therefore, it causes errors of the dose to be irradiated in a patient.

Until now, most of the studies about the effect of CAs on radiation doses were carried out in a phantom instead of a patient [11,12,18]. Therefore, we undertook the present study to examine what the effect of intravenous CA on dose

0167-8140/$ - see front matter doi:10.1016/j.radonc.2006.09.010

distributions of IMRT for head and neck cancer patients is and to investigate its clinical feasibility.

Materials and methods

We performed a treatment-planning study to examine the effect of intravenous CA for planning CTs on the radiation dose distribution of IMRT plans for head and neck cancers. Since intravenous CA is helpful in improving the recognition and delineation of neck nodes as well as tumors from CT images, 15 head and neck cancer patients with neck node involvements who received radiotherapy at Dong-A University hospital and Inje University Paik hospital in Busan, South Korea, were included in the study, which was conducted between June 2005 and September 2005. The patient characteristics are listed in Table 1.

Acquisition of CT

Every patient was immobilized with an individualized thermoplastic mask and a head support in the supine position. They took two sets of planning CTs (HiSpeed NXI, GE Healthcare) from the vertex to about 3 cm below the head of the clavicle. These were initially taken without intravenous CA and then with CA in the same position and coordinates. The enhanced scan (120 kVp, 150 mA) was begun about 5 s after a bolus injection of 90 ml CA (Optiray-320, Mallinckrodt, St. Louis) for 45 s with a power injector, and performed for approximately 15 s. The CA contained 320 mg/ml of iodine. After the acquisition of the CT, the two sets of CTs were transferred to a radiotherapy planning system (Eclipse version 6.5, Varian, Palo Alto, CA) via DICOM and reconstructed into two sets of three-dimensional images.

Table 1
Patient characteristics (n = 15)

Characteristics	Number of patients
Age	
Range	43–79
Median	55
Male/Female	10:5
Site	
Nasopharynx	6
Hypopharynx	3
Oropharynx	2
Layrnx	2
Others	2
T Stage	
Tx	1
T1	2
T2	6
T3	3
T4	3
N Stage	
N1	1
N2	11
N3	3

IMRT planning

For a consistent comparison of all the patients, we tried to standardize the contours of the targets and the OARs and the inverse planning parameters used to generate the dose distribution. The delineation of the targets and the OARs and generation of IMRT plans were performed on the enhanced CTs. The gross target volume (GTV) included the gross tumor and the abnormally enlarged lymph nodes more than 1 cm on CT. Clinical target volume (CTV) 70 was defined as the GTV plus a 5-mm margin. CTV59.4 included the primary tumor site and the nodal levels to which the enlarged lymph nodes belonged. CTV50.4 included the nodal levels which had no enlarged lymph node [7]. PTV70, PTV59.4, and PTV50.4 were defined as the CTV1, CTV2, and CTV3 plus a 3–5-mm margin, respectively. Because selection and delineation of targets were decided primarily to the patients' characteristics, PTV70 and 59.4 were contoured in all patients, but PTV50.4 was not delineated in two patients. Normal organs, which included the parotid glands, spinal cord, eyes, and lens, were also contoured. Partial tongue and vocal cord were included in PTVs in some patients, depending on the disease extent. Therefore, the portion of tongue and vocal cord out of PTV was delineated as a pseudotarget for planning.

IMRT plans were generated from the Eclipse planning system, which corrected tissue density inhomogeneity with a pencil beam convolution method, and adjusted to the accelerator (Varian 2100EX with a 120-leaf millennium collimator, Varian Oncology System) with a 6-MV photon. Nine equiangular beams were used in the IMRT plans. The PTV70, PTV59.4, and PTV50.4 were prescribed to 70, 59.4, and 50.4 Gy for 33 fractions, respectively. The aims of the IMRT plan were that 95% of the PTV should receive the prescribed dose and the maximal and minimal dose of the PTV should be less than 115% and more than 95% of the prescribed dose, respectively. The maximal dose delivered to the spinal cord was kept below 50 Gy and no more than 5% of the spinal cord should receive more than 45 Gy. The maximal dose to the lens was kept below 5 Gy. To make the dose delivered to the parotid glands as low as possible, we modified their constraints repeatedly. After multiple iterations to meet the treatment objectives and no further improvement in optimization, the IMRT plans were adopted. The intensity maps of the IMRT plans were converted into multileaf collimator sequence files, which specified the leaf positions by a sliding window mode as a function of the monitor units (MU) delivered.

After completion of an IMRT plan with the enhanced CT, the CT was fused with the non-enhanced CT taken at the identical coordinates. The contours of the targets and the OARs were copied and replaced from the enhanced CT to the non-enhanced CT. And the beam characteristics of the IMRT plan generated from the enhanced CT were copied and applied to the non-enhanced CT, which included radiotherapy fields, leaf sequences, and MUs. After that, radiation doses were calculated again from the non-enhanced CT by an IMRT plan.

Analysis

To evaluate the equivalence of the patient's positions and coordinates between the two sets of CTs with and