Radiotherapy and Oncology 86 (2008) 177–181
www.thegreenjournal.com

Secondary malignancies

Estimation of risk of radiation-induced carcinogenesis in adolescents with nasopharyngeal cancer treated using sliding window IMRT

Shamurailatpam Dayananda Sharma[a,*], Ritu Raj Upreti[a], Siddhartha Laskar[b], Chandrashekhar M. Tambe[a], Deepak D. Deshpande[a], Shyam K. Shrivastava[b], Ketayun A. Dinshaw[b]

[a]*Department of Medical Physics, and* [b]*Radiation Oncology, Tata Memorial Hospital, Parel, Mumbai, India*

Abstract

***Purpose*: To estimate the risk of radiation-induced carcinogenesis based on whole-body dose measurement on adolescent patients undergoing intensity-modulated radiotherapy (IMRT).**

***Methods and materials*: Ten adolescent patients with nasopharyngeal cancer were planed and treated to a dose of 70.2 Gy using sliding window IMRT. Peripheral dose (PD) was measured using thermoluminescent dosimeters kept at anterior, lateral and posterior positions of each axial plane at the level of xiphoid process, umbilicus and gonads of every patient. The associated risk of radiation-induced carcinogenesis was estimated based on the measured whole-body dose and using age- and sex-specific ICRP-60 nominal probability coefficient of 7.5% (boys) and 9.5% (girls) per Sv.**

***Results*: In all patients, measured PD per monitor unit (MU) decreases almost exponentially with out-of-field distance and varies with gantry angle. Highest whole-body dose equivalent ranged from 0.5318 to 0.9867 Sv (mean = 0.8141 Sv, SD = 0.138) which was measured posteriorly at the level of xiphoid process. Whole-body dose was represented by the average dose at xiphoid process and all measurement positions ranged from 0.3661 to 0.8766 Sv (mean = 0.658 Sv, SD = 0.16) and 0.2267 to 0.5277 Sv (mean = 0.3859 Sv, SD = 0.09), respectively. The associated mean risk of radiation-induced carcinogenesis estimated based on different representation of mean whole-body dose was 6.57%, 5.3% and 3.11%, respectively. Higher mean risk of 7.32% was estimated among girls as compared to 6.25% for boys.**

***Conclusions*: Knowledge of risk of secondary malignancy is particularly important in adolescents and should be considered when choosing the optimal treatment technique and delivery system.**

Keywords: Intensity-modulated radiotherapy; Peripheral dose; Second malignancy; Adolescents

Intensity-modulated radiotherapy (IMRT) is widely adopted in the treatment of several types of cancers in adult and elderly patients because of its potential to reduce normal tissue complication probability. In the recent past, increasing interest has been shown in the use of this technique for adolescent patients. Review of published data on IMRT in adolescent patients reveals significant reduction of dose to lens, optic nerve, optic chiasm, spinal cord and cochlea as compared to conventional radiotherapy in a series of adolescent patients treated for various intracranial tumors [12]. However, despite the promises, two major concerns often raised on the use of IMRT are the increase in whole-body dose due to the increase in the number of monitor units (MU) per target dose and larger volume of normal tissue irradiated at lower radiation dose as compared to conventional radiotherapy [1–4,6,8,10,13,16]. These two factors can potentially increase the risk of radiation-induced carcinogenesis, particularly in long-term survivors [1–4,6–8,10,16].

The whole-body dose and associated risk of radiation-induced second malignancies have been reported from adult and elderly patients treated using various methods of IMRT [1,2,7,8,10,16]. Radiotherapy of adolescent patients using IMRT needs special consideration as the issue related to radiation-induced carcinogenesis is more pronounced in this patient population because (a) adolescents are more sensitive to radiation-induced cancer than are adults and (b) they may survive long enough after disease control [4]. Moreover, risk of carcinogenesis reported so far in the literature was based on the estimate using the nominal probability coefficient of International Commission on Radiological Protection (ICRP) Report No. 60 and National Council on Radia-

0167-8140/$ - see front matter doi:10.1016/j.radonc.2007.11.019

tion Protection and Measurements (NCRP) Report No. 115 for the whole population [5,11]. The current study was undertaken to measure peripheral dose (PD) in adolescent patients undergoing IMRT treatment in head and neck region. The associated risk of radiation-induced carcinogenesis was estimated using age- and sex-specific risk coefficients of ICRP Report No. 60.

Methods and materials

Ten adolescent patients (7 boys and 3 girls) aged between 13 and 18 years (mean = 14.5 years), undergoing IMRT treatment of nasopharyngeal cancer using sliding window techniques were enrolled in this study. All patients were planned and treated as per standard IMRT protocol of the institute. Optimization, dose computation and leaf sequencing were performed on Eclipse V 7.3.1 (Varian Associates, Palo Alto, CA) treatment planning system (TPS). Seven (in 4 patients) and nine (in 6 patients) co-planar fields was employed for each patient plan. The gantry angles used in the 7-fields IMRT plan were 80°, 120°, 150°, 180°, 210°, 240° and 280°. While for the 9-fields IMRT plan another two anterior oblique portals with gantry angle 40° and 320° were added in the beam geometry of the 7-field plan. In patients with large tumors, wherein field size larger than 14.5 cm were employed in axial (*X*) directions, intensity modulated fields were automatically split into two parts using the dose feathering methods available in the Eclipse TPS. All patients were treated to a dose of 70.2 Gy in 33 fractions on Clinac 6-EX linear accelerator (Varian Associates, Palo Alto, CA) using 6 MV X-rays. Varian Clinac 6-EX is a single energy (6 MV X-rays), vertical waveguide linear accelerator and is equipped with Millennium 120 leaf MLC as tertiary collimator and amorphous silicon electronic portal imaging device (EPID). The projected leaf width at isocenter for the central 40 leaf pairs was 0.5 cm while the peripheral 20 pairs were 1 cm each. The maximum field size achievable with this MLC is $40 \times 40\ cm^2$.

In-patient measurement

Measurements of PD were carried out on these ten patients using thermoluminescent dosimeter (TLD). For every patient, three axial planes at the level of xiphoid process, umbilicus and gonads were chosen for the measurement. In each axial plane, three locations: anterior, right lateral and posterior, were selected corresponding to the isocentric plane of the patient. Thus there were nine measurement positions for each patient. The distances of these positions were measured from the central axis for every patient and along with the aid of room lasers were used for the subsequent placement of TLD chip during in-patient measurements. The distances of the anterior measurement positions from the central axis, average jaws dimension and MU required to deliver the total dose from each IMRT plan are summarized in Table 1. Three TLD-100 chips (LiF:Mg,TI, Harshaw, USA) having dimensions of $0.32\ cm \times 0.32\ cm \times 0.09\ cm$ contained in a polystyrene pouch were placed at each measurement position of every patient. For each patient PD measurements were performed for four consecutive fractions to obtain an optimal TL output. Precautions were taken to ensure accurate repositioning of the TLD chips during the four consecutive measurements. Whole-body dose equivalent was reported as (a) maximum dose measured at a single location, (b) average of the dose measured at anterior, posterior and lateral positions at the level of xiphoid process and (c) average of the doses measured at all the nine locations.

TLD reading

TL chips used in this study could detect doses ranging from 20 μSv up to 1000 Sv and were pre-selected from the same batch having reproducibility within ±2% in the low dose region. The exposed TL chips were read after 24 h of the last exposure using a commercially available TLD reader (REXON Model UL-320, Rexon TLD systems Inc., USA). For each batch of TLDs read in the current study, the TLD reader was calibrated in secondary standard laboratory by using five zero-dose control TLDs and five sets of calibration TLDs irradiated to known doses of 0.01, 0.03, 0.05, 0.1, 0.2, and

Table 1
Distances of the anterior measurement positions from the central axis and total MU required for delivering total dose of 70.2 Gy from the IMRT plan of every patients

Patient	Age (year)/sex	No. of fields	Average jaws setting ($X \times Y$) (cm^2)	Distance of anterior measurement points from the central axis (cm)			Total MU for 70.2 Gy in 33 fractions
				Xiphoid process	Umbilicus	Gonads	
1	13/M	9	15.9 × 19.6	24	40	56	50,622
2	17/M	7	15.8 × 20.7	28	46	67	41,250
3	17/F	9	15.8 × 20.0	30	46	63	46,002
4	13/M	9	18.2 × 17.9	25	41	56	45,441
5	16/M	9	16.9 × 18.4	24	43	60	42,947
6	16/M	9	15.7 × 18.8	26	44	59	37,587
7	18/F	7	14.8 × 20.5	27	46	64	25,279
8	18/M	7	14.6 × 17.8	29	47	65	31,647
9	16/F	9	17.2 × 18.5	24	43	60	42,853
10	13/M	7	15.1 × 17.5	23	37	54	31,944