Assessment of radiation dose to eye lens during RapidArc treatment of Head and Neck cancer patients

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Abstract. The present study aimed to evaluate radiation dose to eye lens in head and neck cancer patients treated with RapidArc™. The in-vivo dosimetry was performed and radiation doses to eye lens were assessed using a commercially available OSLD dosimetry system. Twenty head and neck cancer patients were recruited in the present study. The patients were treated using 6 MV X-Ray photon energy RapidArc™ dual arc (1 isocenter, two full arcs, ±30º collimator angle) technique. In the present study, the malignancy site of the maxilla was found to contribute the highest radiation dose to eye lens and the malignancy site of vocal cord contributed the lowest radiation dose to the eye lens. It was observed that the eye lens radiation dose was dependent on the distance of the eye from the PTV edge. The average cumulative radiation dose to eye lens was estimated to 42 cGy with RapidArc™ treatment of head and neck cancers.

KEYWORDS: Eye lens dose, Rapid Arc, Optically stimulated luminescence (OSL) dosimetry

1. INTRODUCTION

The assessment of radiation doses is required for patients during radiological procedures and In-Vivo Dosimetry (IVD) is a recommended procedure [1, 2]. Thermo Luminescence Dosimeter (TLD), Optically Stimulated Luminescence Dosimeter (OSLD), PN junction-type diodes, or Metal Oxide Semiconductor Field-Effect Transistor (MOSFET) are frequently used in-vivo dosimeters to serve desired purpose [3, 4]. There are several popular passive dosimeters commercially available in the market for TLDs such as $CaSO_4$: Dy, LiF: Mg, Cu, LiF: Mg, Ti and OSLDs such as Al_2O_3: C which are used extensively worldwide. The OSL technique became a successful tool in personal and environmental radiation dosimetry, geological and archaeological dating, retrospective/accident dosimetry, and medical applications of radiation in diagnostic imaging and radiotherapy in the last two decades. The use of OSL for radiation dosimetry was first suggested in the 1950s and 1960s [5, 6]. OSL utilises materials and electronic processes similar to Thermo Luminescence (TL) but the interrogation of the detector is performed by light (ultraviolet, visible or infrared) instead of heat and emits a light signal; the wavelength of the emitted light is a characteristic of OSL material and the intensity of the emitted light signal is proportional to the irradiation radiation dose. High sensitivity, precise delivery of light, fast readout times, simpler readers and easier automation are the main advantages of OSL in comparison with TLD. OSL allows for re-reads of the detector multiple times while maintaining the precision, and it can be used as an erasable measurement technique [7, 8].

Head and neck cancers are the most common cancer among males in India. The malignancy location is generally present in the oral cavity, nasal cavity, paranasal sinuses, tongue, salivary glands, larynx and pharynx including the nasopharynx, oropharynx and hypopharynx [9]. Volumetric Modulated Arc Therapy (VMAT)/ RapidArc™ is an important and advanced external beam radiotherapy (EBRT) technique for the treatment of head and neck malignancies. The potential higher doses to eye lens may result in several radiation-induced deterministic effects such as visual impairments and radiation-induced cataractogenesis. [10, 11]. There are several Organ At Risks (OAR) such as the eye lens, thyroid, salivary glands, brainstem, spinal cord and red bone marrow etc. during the radiotherapy of head and neck cancer patient. The present study was aimed to assess radiation dose to eye lens for the head and neck cancer patients treated with RapidArc™**.**

2. MATERIALS AND METHODS

2.1 Description of treatment

The present study was a prospective and single centre research study design. Twenty patients with head and neck cancer patients were randomly assigned to participate in the present study after obtaining written informed consent. The inclusion criteria of the patient in the study were having disease extended bilateral and curative intent. The patient age (range, 38 - 65 years; mean, 51 years) treated with the volumetric modulated arc therapy (VMAT)/ Rapid Arc™ which is a form of external beam radiation therapy (EBRT). Computed Tomography (CT) scan of the patient in the supine position using immobilization device performed on Somatom Scope 32 slice multislice CT scanner (Siemens Shenghai Medical Equipment Limited, China) 3-mm CT slice thickness. CT images were analyzed for contouring on SomaVision workstation (Varian Medical Systems, Inc., Palo Alto, CA, USA) where the target volumes such as Planning Target Volume (PTV) and normal tissue structures were delineated by a single radiation oncologist as per the recommended guidelines of International Commission on Radiation Units and Measurements (ICRU62) to avoid any inter-observer disagreement [12]. All the patients were planned with Eclipse Treatment Planning System (TPS) version 13.7 (Varian Medical Systems, Inc., Palo Alto, USA). The patients were treated with 6 MV X-Ray photon energy RapidArc™ dual arc (1 isocenter, 2 full arcs, ±30º collimator angle) technique for a maximum dose rate of 600 Monitor Units/Minutes using Trilogy (Varian Medical Systems, Inc., Palo Alto, USA) linear accelerator (Linac) equipped with 60 pair Millennium Multi-Leaf Collimator (MLC) as shown in Fig. 1. The treatment unit 'Trilogy with FFF (Flattening Filter Free)' is dual photon energy (6 & 15 MV) Linac with a single 6 MV FFF energy. The Linac have 6, 9, 12, 15, 18 MeV electron energies. The maximum field size of 40 × 40 cm^2 can be possible with the 120 Millennium MLC.

Figure 1: Varian Trilogy with FFF unit with Millennium 120 MLC equipped with image-guided radiotherapy (IGRT) modalities cone beam computed tomography (CBCT) and Megavoltage imaging with trade name On-Board Imaging (OBI) and Electronic Portal Imaging Device (EPID) respectively

The 6MV X-ray photon energy was used for the treatment of head and neck cancer patients in the present study. The two full arcs were delivered in opposite rotations (clockwise and counterclockwise direction). The collimator was set to rotate to a value other than zero in order to avoid tongue and groove effect. The patients treated with external beam radiotherapy Rapid Arc™ mode with a conventional fractionation regime, with a radiation dose prescription of conventional fractionation regime of 70Gy/35 fractions, at a dose delivery of 2 Gy/fraction. The patient-specific Quality Assurance (QA) was performed using Varian amorphous silicon (aSi) portal dosimetry with standardized portal dose image prediction (PDIP) algorithm configuration. The plans were approved with an area gamma passing rate (3%, 3mm) greater than 95% for gamma analysis dose tolerance 3% and distance to point agreement (DTA) 3 mm criteria. A brief description of radiotherapy treatment is presented in Fig. 2. Planar kilovoltage (kV) and Cone Beam Computed tomography (CBCT) imaging

with On-Board Imaging (OBI) was used for image-guided patient position verification for RapidArc™ treatment in the present study. However, the imaging dose was not accounted for in the final radiation doses values. A set of information was recorded from each participant, such as patient ID, patient characteristics, age, skull size, target volume, Monitor Units (MU) delivered during radiotherapy treatment, the distance of planning target volume (PTV) from eyes etc. These data were collected and analyzed to present the outcomes of the study.

Figure 2: Brief description of patients and treatment details included in the present study

Patient characteristics	**Head and neck cancer patients**
CT scan	**3 mm slice thickness in supine position using immobilization device**
Contouring	**Target structures and OARs were contoured as per recommended guidelines of ICRU62.**
Treatment unit	**Varian Trilogy with FFF equipped with 120 Millennium MLC**
Treatment Planning	**Eclipse version 13.7 with AAA dose calculation algorithm and dose calculation grid 2.5 mm**
Dose prescription	**70 Gy/ 35 Fractions**
Treatment Delivery	**RapidArc mode with dual arc delivery and single isocenter technique**
Patient specific QA	**Varian amorphous silicon (aSi) portal dosimetry with portal dose image prediction (PDIP) algorithm configuration**

2.2 In-vivo dosimetry

The OSL reader and dosimetry system (Landauer Inc., Glenwood, IL, USA) was used to assess radiation doses. The InLight microStar® OSLD reader and OSL dosimeters are shown in Fig. 3 and Fig. 4 respectively. The OSL dosimeters were from Landauer Inc., Al_2O_3:C nanoDots™ (10 X 10 X 2 mm). The complete reader system consists of a barcode scanner to facilitate record keeping and data entry, a loader to load dosimeter in reader for readout and a laptop to show readout result and record keeping of data.

Figure 3: InLight microStar® OSL Reader System, Landauer Inc., US having OSL Reader display unit and system. Measurements with exposed OSL nanoDots were obtained with 525 nm green excitation laser and trapped information is received in the form of radiation dose

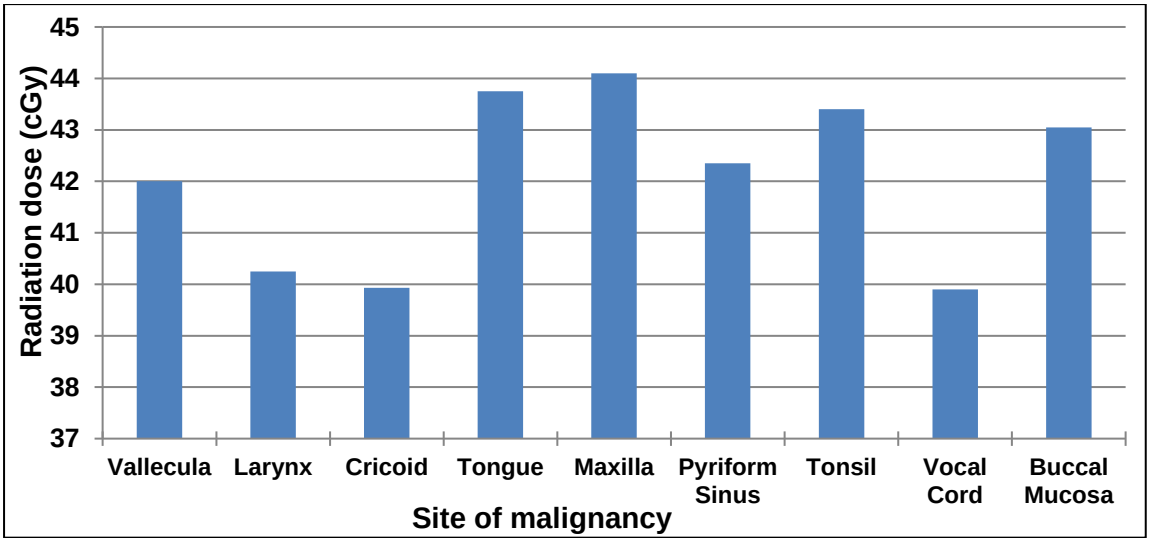
Figure 4: Three OSL nanoDot™ from Landauer Al_2O_3:C as active material placed in different orientation presenting (left) back, (middle) front and (right) side on the profile of closed dosimeter. The closed dosimeter outer plastic case dimensions (10 X 10 X 2 mm) with Large plastic holder

The eye lens doses were assessed by placing the dosimeter as close as possible to the eye in contact with orfit. After completing the treatment, nanoDots™ were removed carefully and kept away from the radiation area about 10 minutes for dose stability [13-15]. OSL dosimeters were calibrated prior to measurement and dose-response variation was found within ±5%. The OSL nanoDots™ were read out with the help of the OSLD reader dosimetry system. Each OSL nanoDot™ was readout three times for estimation of accurate mean dose. The measurements for each patient have been performed for three consecutive radiotherapy treatment fractions and average reading was considered as eye lens dose per fraction in order to reduce uncertainty in measurement.

3. RESULTS AND DISCUSSION

The total target volume was recorded in range, 338 – 560 cc; mean, 460 cc. The distances of planning target volume (PTV) edge from eyes were found in range, 3.0 – 8.7 cm; mean±SD, 4.5±2.8 cm. It was observed that maximum eye lens dose was received during the treatment of cancer of the maxilla. The radiation dose was measured 1.26 cGy per fraction for a mean dose delivery of 200 cGy/ #, i.e. 0.63% of the tumour dose. At the end of the EBRT, the eye lens would have received a total estimated radiation dose of 44.10 cGy in 7 weeks. Whereas during the treatment of Cancer of Vocal cord was responsible for the minimum eye lens mean dose 1.14 cGy per fraction for a dose delivery i.e. 0.57% of the tumour dose. At the end of the EBRT, the eye lens would have received a total estimated dose of 39.90 cGy in whole treatment fractions. The results are presented in Fig. 5.

Figure 5: Graphical representation of radiation doses measured during RapidArc™ treatment of various head and neck cancers



Further, it was observed that the minimum eye lens dose was received due to the greater distance of the eye from the PTV edge. The results of the present study reported that there was no significant correlation observed in eye lens radiation doses with respect to the target volume and average MUs delivered during RapidArc™ treatment. The average cumulative radiation dose to eye lens was estimated 42 cGy with Linac RapidArc™ treatment of head and neck cancers. The cumulative radiation dose to eye lens in whole RapidArc™ treatment was found lesser than the ICRP recommended threshold absorbed dose for the occurrence of the deterministic effect of radiation. IVD is able to assess radiation doses and detect gross errors during delivery of radiotherapy. The present study recommends that the installation of IVD tools shall be a mandatory regulation for use during radiotherapy of patients.

4. CONCLUSION

The radiation dose to eye lens is critical and important. Our results show that the assessment of radiation dose to eye lens is recommendatory during radiotherapy treatment of curative cancer patients. In-vivo dosimetry is a reliable method to verify the safe delivery of radiotherapy.

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