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QUANTIFICATION OF DOSIMETRIC IMPACT OF IMPLEMENTATION OF ON-BOARD IMAGING (OBI) FOR IMRT TREATMENT OF HEAD-AND-NECK MALIGNANCIES

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Abstract—Implementation of daily kilovoltage imaging for setup verification improves the reproducibility of treatment by eliminating small random setup errors. We evaluate the dosimetric consequences of such shifts, not yet evaluated, in a group of head-and-neck cancer patients (ENT) treated with intensity modulated radiation therapy (IMRT) at Emory University. Twelve patients with ENT malignancies were analyzed. On-Board Imaging (OBI) was used in at least 70% of each patient's treatment sessions. An isodose distribution was generated for each fraction, with the isocenter shifted to its calculated location prior to OBI repositioning. These plans were summed and then compared to the simulation plan for coverage of target structures. For these 12 patients, there were a total of 18 planning target volumes (PTV). The mean (range) percent reduction in minimum dose was 12.1% (−1.0 to 43.3). For 10 right necks and 9 left necks treated, the mean percent reduction in minimum dose was 11.8% (−0.6 to 39.7) and 13.3% (−3.6 to 31.2), respectively. The mean reduction in mean dose to the PTV was 1.3% (0 to 5.1). The mean reduction in mean dose to the right and left necks was 1.0% (0.2 to 3.9) and 1.13% (0.4 to 3.4), respectively. From this analysis, we conclude that the shifts made were small and random, with essentially no change in mean dose delivered to target structures. There is, however, significant improvement in the minimum dose delivered. Underdosing even a small portion of the tumor potentially sacrifices the probability of local control; correcting these setup errors seems desirable. © 2007 American Association of Medical Dosimetrists.

Key Words: **On-Board Imaging (OBI), Interfraction motion management, Head-and-neck malignancies, Image-guided radiation therapy (IGRT).**

INTRODUCTION

Current standard technique for verification of patient positioning during a course of radiation therapy involves direct comparison of weekly megavoltage (MV) portal image x-rays to kilovoltage (kV) images generated at the time of patient simulation.[1,2] Accurately verifying patient position using MV portal images is made difficult, as subject contrast is known to be 10 to 20 times lower for MV portal images as compared to diagnostic images, which use x-rays in the kV range.[3,4]

Recent advances in target localization and delivery of treatment have included the acquisition of digital kV x-ray images for assessment of patient positioning. This gives a marked improvement in image quality while also decreasing the dose delivered to the patient as compared to MV portal verification. Use of such a system of kV-kV matching allows for daily orthogonal verification films to be taken and compared to digitally reconstructed radiographs (DRRs) obtained during simulation. Previous investigations have shown that the resultant patient shifts are small and random, without diminution over time.[5]

Intensity modulated radiation therapy (IMRT) has been increasingly used in the treatment of head-and-neck malignancies. Use of IMRT allows for improved sparing of critical normal tissues while avoiding a decrease in local control.[6–10] While conventional treatment plans for head-and-neck (ENT) cancers often involve the use of opposed lateral fields encompassing the tumor, draining lymphatics, and intervening normal tissues, IMRT plans typically conform the high-dose region to the tumor and draining lymphatics, resulting in steep dose gradients at the periphery of target structures.[11] Given the reduced tolerance for error, systems to address intra- and interfraction motion and improve precision have been developed.

Effective and reproducible immobilization is a critical component of management of both intra- and interfraction movement during radiation treatment. Typically for patients with ENT tumors, this is accomplished by use of a thermoplastic mask with a rigid base affixed to the treatment couch. Analysis of directional offsets, typically based on weekly portal images, has shown shifts averaging 3 to 5 mm in any direction, with standard deviations (SDs) of 5 to 8 mm.[12–15] Image-guided radiotherapy (IGRT) has grown out of the desire to further reduce daily setup variation. Implementation of daily

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Table 1. Patient characteristics

Patient	Age (years)	Sex	Histology	Site	Stage	Surgery
1	75	M	Melanoma	Rt Orbit	Recurrent	Rt orbital exenteration
2	46	M	Poorly Diff. SCC	Rt Tonsil	T4aN0	Rt tonsillectomy
3	53	M	Esthesioneuroblastoma	Nasal cavity	Kadish C	Craniofacial resection
4	46	M	Poorly Diff. SCC	Rt Tonsil	T2N2b	Rt tonsillectomy
5	52	M	Well Diff. SCC	Lt Tonsil	T2N0	Biopsy only
6	53	M	SCC	Lt PS	T2N3	Left neck dissection
7	79	M	Mod. Diff. SCC	SGL	T4aNx	Total laryngectomy
8	59	M	SCC	Lt BOT	T4N2c	Biopsy only
9	60	F	Mod. Diff. SCC	Rt BOT	T2N0	Biopsy only
10	68	M	Poorly Diff. SCC	Lt Parotid	T4aN2b	Lt parotidectomy, hemimandibulectomy, Lt neck dissection
11	53	F	Poorly Diff. SCC	Lt Tonsil	T1N2c	Biopsy only
12	74	F	Poorly Diff. SCC	Unknown	TxN2b	Biopsy only

SGL = subglottic larynx; PS = pyriform sinus; BOT = base of tongue; Rt = Right; Lt = Left; SCC = squamous cell carcinoma.

kilovoltage imaging for setup verification attempts to improve the reproducibility of treatment by eliminating the small daily errors in positioning the patient for treatment.[16,17] The dosimetric effects of implementing these shifts have not been fully evaluated.[12,18,19] The aim of our study was to evaluate the dosimetric consequences of such shifts in a group of head-and-neck cancer patients treated with IMRT at Emory University.

METHODS AND MATERIALS

Details of the On-Board Imaging (OBI) apparatus, as well as the implementation of the device, have been previously published.[20] In brief, the system consists of an x-ray tube (model G242, 0.4- and 0.80-mm focal spots, 14° anode angle, 800 kJ per hour; Varian Medical Systems, Inc., Salt Lake City, UT) and an amorphous-silicon imaging panel (model PaxScan® 4030CB, Varian Medical Systems, Inc.) attached 90° to the gantry of the linear accelerator with Exac™ robotic arms (Varian Medical Systems, Baden, Switzerland). Three motorized pivot points on the robotic arms allow OBI to be remotely extended or retracted from the control console station. Orthogonal OBI images are acquired and then compared to reference images from simulation digitally reconstructed radiographs (DRR) using a dedicated OBI software system. Either automatic or manual matching can be performed; our institution has employed manual matching nearly exclusively.[20]

For this retrospective analysis, we evaluated 12 patients treated in our department from April 2005 to August 2005 for various newly diagnosed ENT malignancies. The selected patients were the first 12 to be treated for ENT malignancies and to have OBI used in at least 70% of their treatment fractions. There were 6 patients with oropharyngeal primaries, 1 with a laryngeal primary, 1 with a hypopharyngeal primary, 1 with a cancer of the nasal cavity, 1 with a parotid gland tumor, 1 with an unknown primary, and 1 with a recurrent melanoma of the orbit. The histology of each was squamous cell carcinoma, with the exceptions of the orbital melanoma and esthesioneuroblastoma arising in the nasal cavity. T classification was as follows: TX (1 patient), T1 (1 patient), T2 (4 patients), and T4 (4 patients). Four patients had N0 disease, 5 were staged N2, and 1 had N3 disease. The esthesioneuroblastoma was Kadish Stage C; the melanoma was a multiple recurrent lesion. Mean (range) dose prescribed to primary disease was 67.82 Gy (60 to 70.29 Gy), at a mean of 2.09 Gy/fx (1.91 Gy/fx to 2.13 Gy/fx). The mean prescribed dose and dose per fraction for treated left and right necks were 59.6 Gy (55.8 to 63.03 Gy) at 1.83 Gy/fx (1.73 Gy/fx to 1.97 Gy/fx) and 59.32 Gy (51.0 to 67.98 Gy) at 1.82 Gy/fx (1.70 Gy/fx to 2.06 Gy/fx), respectively. The details of each patient as well as surgical procedures performed are presented in Table 1.

Following standard thermoplastic mask immbolization, thin-cut contrast-enhanced computed tomography (CT) images of the patients were acquired for treatment planning. Treatment planning was performed using the Eclipse system from Varian (Varian Medical). For patients treated definitively, delineation of tumor volumes was accomplished with fusion of CT-PET (positron-emission tomography) scans to the planning CT scan. Structures designated as gross tumor volume (GTV) included areas shown to be involved by tumor on the basis of the diagnostic or simulation CT scan or PET scan; the GTV included both primary disease as well as nodal volumes involved with tumor. The total margin added to GTV for the creation of the planning target volume (PTV) was typically 1 to 1.5 cm, with modifications to accommodate sparing of critical normal structures made at the discretion of the treating physician. For patients treated postoperatively, tumor bed contours were generated from fusion of preoperative CT scans with scans obtained during simulation. Unique PTVs were created for at-risk neck nodal regions, which were contoured separately.[21–23]

Critical normal tissues typically contoured include spinal cord, brainstem, parotid glands, submandibular