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Dosimetric comparison of helical tomotherapy, intensity-modulated radiation therapy, volumetric-modulated arc therapy, and 3-dimensional conformal therapy for the treatment of T1N0 glottic cancer

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ABSTRACT

Various radiotherapy planning methods for T1N0 laryngeal cancer have been proposed to decrease normal tissue toxicity. We compare helical tomotherapy (HT), linac-based intensity-modulated radiation therapy (IMRT), volumetric-modulated arc therapy (VMAT), and 3-D conformal radiotherapy (3D-CRT) techniques for T1N0 laryngeal cancer. Overall, 10 patients with T1N0 laryngeal cancer were selected and evaluated. Furthermore, 10 radiotherapy treatment plans have been created for all 10 patients, including HT, IMRT, VMAT, and 3D-CRT. IMRT, VMAT, and HT plans *vs* 3D-CRT plans consistently provided superior planning target volume (PTV) coverage. Similar target coverage was observed between the 3 IMRT modalities. Compared with 3D-CRT, IMRT, HT, and VMAT significantly reduced the mean dose to the carotid arteries. VMAT resulted in the lowest mean dose to the submandibular and thyroid glands. Compared with 3D-CRT, IMRT, HT, and VMAT significantly increased the maximum dose to the spinal cord It was observed that the 3 IMRT modalities studied showed superior target coverage with less variation between each plan in comparison with 3D-CRT. The 3D-CRT plans performed better at the D_{max} of the spinal cord. Clinical investigation is warranted to determine if these treatment approaches would translate into a reduction in radiation therapy–induced toxicities.

Introduction

Larynx cancer is one of the most common head and neck cancer malignancy, and approximately half of these malignancies present as an early stage (T1N0-T2N0). Successful treatment options include surgery and radiation therapy (RT), but no single modality has been proven to be superior to the other.[1] The end goal of treatment is larynx preservation, high voice quality, and minimal morbidity. Therefore, RT has been considered as a mainstay treatment approach for early-stage patients.[2,3] Conventionally, RT has been delivered using 2 small, parallel opposed radiation fields, often using hypofractionated schedules. This technique is proven to be very effective but unfortunately does not allow dose sparing of the organs at risk (OAR) in the neck including carotid arteries, skin, thyroid gland, and often submandibular glands. Carotid artery damage after radiotherapy leads to increased thickness of carotid intima-media, subsequently resulting in increased incidence of atherosclerosis and higher chance of cerebrovascular accidents.[4] Newer RT techniques such as tomotherapy and linac-based intensity-modulated RT (IMRT) and volumetric-modulated arc therapy (VMAT) with RapidArc (RA) have been developed that allow superior dose conformality to treatment target volumes and provide steep dose gradients to nearby uninvolved structures.[5,6] Many institutions have recently incorporated IMRT with different devices into the treatment of early-stage glottic cancer for selected patients.[7] To date, there are limited data directly comparing all different radiotherapy modalities and treatment strategies for early-stage larynx cancer. This is the first study comparing

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dose-volume histograms (DVHs) of target volumes and normal tissue structures in tomotherapy-based IMRT *vs* RA-based VMAT plans using both fixed target volumes and adaptive planning for patients with early-stage larynx cancer.

Methods and Materials

A total of 10 patients with T1N0M0 squamous cell carcinoma of the vocal cord suitable for treatment using a hypofractionated radiotherapy schedule were selected for this study. All suspicious lesions were biopsied, and pathology slides were reviewed by an expert in head and neck pathology at Inonu University. Patients were staged with any combination of direct laryngoscopy, computed tomography (CT), and magnetic resonance imaging (MRI) scans. Patients were immobilized in the supine position with a 5-point thermoplastic mask. Treatment planning CT scans were obtained from the top of the skull to the lower part of the neck with a 3-mm slice thickness. Intravenous contrasting agent (Iopamidol, 1 mg/kg of body weight) was used in all patients. All patients were treated using a helical tomotherapy (HT)—based IMRT technique. HT planning was performed using tomotherapy Hi-ART planning systems software version 4.2.1. Patients were treated to the larynx region without elective nodal irradiation. CT simulation data sets for the treatment of RT history were obtained for all 10 patients.

The HT multileaf collimator leaf width used is 6.25 mm in IEC-X direction at isocenter. Images and structure sets were then imported into treatment planning systems to create RA, linac-based IMRT, and 3-DCRT plans. Treatment plans were created by 3 separate medical physicists at 3 separate cancer therapy centers. Overall, 4 treatment plans were created for each treatment modality to be studied (HT, 3-D conformal radiotherapy [3D-CRT], IMRT, and VMAT). VMAT, linac-based IMRT, and 3-D CRT plannings were performed using an Eclipse version 13.0 (Varian Medical Systems Inc., Palo Alto, CA). For the IMRT and VMAT plans, Varian HD MLC system with 2.5-mm leaf width was used. The target volumes were delineated following our institutional guidelines for contouring. The clinical target volume (CTV) extended superiorly from the cranial border of the thyroid cartilage, inferiorly till the caudal end of the cricoid cartilage, anteriorly included the anterior edge of the thyroid cartilage, posteriorly included the arytenoid cartilage, and laterally the entire thyroid cartilage was included within the CTV. A 5-mm margin was applied to CTV in all axes as per institutional policy to create the planning target volume (PTV). OARs contoured included the spinal cord, bilateral carotid arteries, submandibular glands, and thyroid gland. Bilateral carotid arteries were contoured from superior edge of the skull base up to inferior edge of the sternoclavicular joint. We contoured a ring that extends the PTV by 8 mm in all directions to have a more homogeneous plan. All plans used the same OAR, CTV, and PTV delineations.

The dose prescription was 6300 cGy in 225 cGy fractions over a course of 38 days, and plans were normalized as at least 95% of the PTV was required to be covered by the at least 95% isodose of 63 Gy. No point dose outside PTVs was $>105\%$ of the prescribed dose and no point dose within PTVs was $>110\%$ of the prescribed dose. DVHs of PTVs and OARs were generated for 3-D CRT, IMRT, Tomoterapy, and RA plans to compare doses with tumor volumes and normal structures.

The 3D-CRT plans used the traditional opposing 2-field lateral coplanar or noncoplanar beams. Beams were individually optimally weighted to provide adequate PTV coverage. Bolus was not required for these plans. IMRT plans used 3 optimally positioned beams per patient with "step and shoot" treatment delivery. RapidArc treatment plans used 2 partial arcs for treatment. HT uses field width, pitch, and modulation factor variations to optimize plans. A field width of 1 cm, modulation factor of 2.3, and pitch of 0.287 were used to produce the HT plans. All plans were generated with 6-MVphotons using a multileaf collimator. An example of typical patient plans and DVHs with the 4 treatment modalities is shown in the Fig.

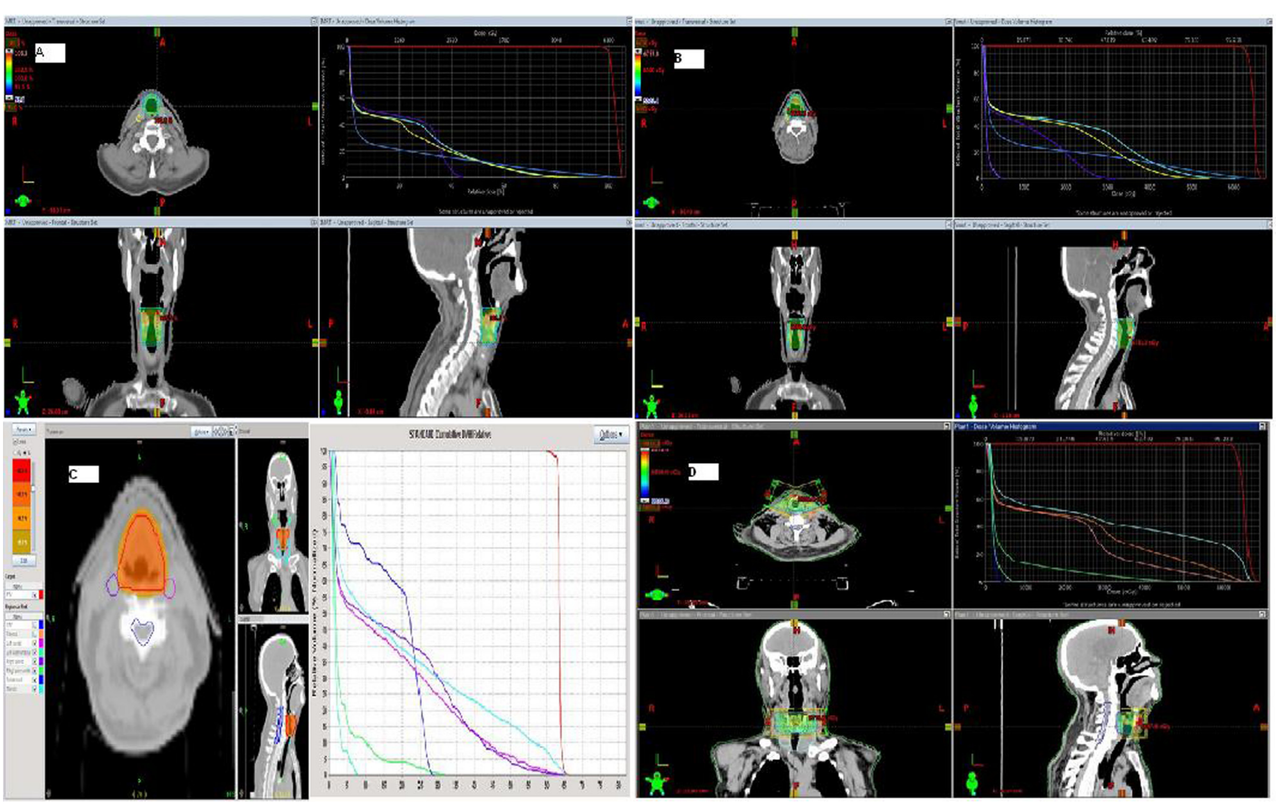

Fig. Dose distributions and dose-volume histograms of 4 planning techniques: (A) IMRT, (B) VMAT, (C) HT, and (D) 3D-CRT. (Color version of figure is available online.)