A Comparative and Dosimetric Analysis Regarding the Practical Use of 3D Conformal, IMRT, Rapid Arc, and Proton Therapy for the Treatment of T1/T2 Glottic Laryngeal Cancer

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INTRODUCTION

Larynx cancer is the most common head and neck malignancy in the United States, and approximately half of all patients present at an early disease stage (T1-T2N0M0). Successful treatment options include surgery and radiation therapy (RT), but no single modality has been proven superior for larynx cancer is disease cure with minimal treatment morbidity and larynx preservation, therefore RT has been considered a mainstay treatment approach for early stage patients.

The traditional established technique for early larynx RT includes the use of small, parallel opposed lateral fields. Treatment with this technique is proven to be very effective, but unfortunately does not allow dose sparing of the adjacent structures in the neck including the skin, carotids, and thyroid gland. Several previous studies have suggested that irradiation of the neck increases the risk of long term cerebrovascular complications. Other authors have already suggested to continue the traditional approach of opposed lateral fields in favor of more complex techniques to reduce the carotid dose. Other concerns regarding RT for early glottic cancers include the known risk for the development of a metachronous second primary head and neck cancer, and the limitations that a previous radiation course places on the capabilities of reirradiation of the neck for subsequent situations. Metachronous second primary head and neck cancers are known to contribute significant mortality to patients treated with RT for previous head and neck cancer.

Newer RT techniques such as intensity modulated radiation therapy (IMRT) have developed which allow better dose conformity to treatment targets and steep dose gradients to nearby uninvolved structures. Rapid-Arc allows similar treatment conformity with the addition of reduced treatment times. Proton therapy has also been increasing in usage and consideration of head and neck treatment due to the benefits of the Bragg-peak dose distribution to spare uninvolved tissues.

Given the high efficacy and relatively minimal toxicity of larynx irradiation compared to surgery, increasing interest has developed to consider approaches that reduce the RT dose to uninvolved adjacent tissues and potential subsequent long term morbidity. Therefore, in this study we aimed to compare dosimetrically these four treatment modalities for a practical treatment plan for T1-T2N0M0 glottic cancer in the clinic. We then planned to discuss the issues surrounding this topic regarding patient treatment.

MATERIALS and METHODS

- 10 patients selected from database having T1-T2 glottic squamous cell carcinoma and treated with radiotherapy.
- Previous CT simulation data was utilized which was performed on a Phillips Brilliance Wide Bore 16 slice CT scanner.
- Photon treatment planning was performed using Eclipse External Beam Planning 7.5.51 (Varian Medical Systems, Palo Alto CA), proton planning was performed using CMS Xio 4.63 (Elekta).
- A standard CTV delineation for all patients was performed and included contouring of the larynx excluding the supraglottic cartilages, false and true vocal cords, interior and posterior commissures, aryepiglottic folds, and 1-1.5 cm of subglottis. A planning target volume (PTV) was generated by expanding this volume 5 mm.
- Organs at risk (OAR) contoured included the spinal cord, bilateral carotids, thyroid, and non-target body. Organs at risk were expanded 3-5 mm to create planning risk volumes (PRV), and the carotid / spinal cord OAR volumes were expanded 1 cm cranial / caudal to the PTV.

- 3D conformal treatment plans used the traditional two opposed lateral coplanar or non-coplanar beams technique. IMRT plans utilized five individually and optimally positioned beams per patient with “step and shoot” treatment delivery. Rapid Arc treatment plans utilized one arc per treatment. All photon plans were generated utilizing a multi-leaf collimator (MLC) for blocking, and energy 6 MV. Proton treatment planning utilized three uniform scanning beams with appropriate aperture and range compensators. Multiple approaches with different numbers of beams, angles, and segments were evaluated for each individual patient and plan. Each course was tailored to each specific patient for goal of achieving the “best achievable plan”. Matching PTV coverage and OAR volume dose consideration. All courses were planned at 2.25 Gy to 63 Gy total, and normalized so that > 95% of the PTV (relative volume) received 100% of the prescription dose.

RESULTS

- Forty treatment plans were successfully completed for the ten patients. Figure 1 shows a representative 3D conformal plan and Rapidarc plan.

CONCLUSIONS

All treatment modalities covered the V95 adequately. Rapid arc and proton planning resulted in significant decreases in dose to the carotid arteries with clinically acceptable doses given to the spinal cord. All modalities were found to be superior when compared with 3D conformal therapy. The data shows that multiple approaches are feasible with radiotherapy techniques for early stage larynx cancer, and reductions of dose to uninvolved tissues are quite achievable to varying degrees among the various approaches. A clinical study is necessary and patient follow-up to determine if these dosimetric achievements result in equivalent or superior efficacy and reduction in patient morbidity.

Dose to the Planning Treatment Volume (PTV) and Clinical Treatment Volume (CTV)

For all plans, 100% of the prescription dose (63 Gy) encompassed > 95% of the PTV. For 3D, IMRT, rapid arc (RA) and Proton plans, the average maximum dose (Dmax) was 66 Gy, 70 Gy, 69 Gy, and 70 Gy. The average mean dose (Dmean) was 64 Gy, 66 Gy, 65 Gy, and 63 Gy respectively. Statistical significance (p < 0.05) was determined comparing PTV and CTV coverage dose ranges (Dmean, Dmax, D95) for 3D vs. IMRT/RA/ proton, and IMRT vs. RA/proton, and RA vs. Proton.

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