AbstractID: 10093 Title: A Computational Study of Intensity Modulation Radiation Therapy (IMRT) Treatments of Head and Neck, and Prostate Cancers.

SUPPORTING DOCUMENT FOR YOUNG INVESTIGATOR:

Head and neck (HN) cancer patients account for approximately 3 to 5 percent of all cancers, and are more common in men and in people over age 50 in the United States. Radiation therapy treatments of the HN sites can lead to the disease control, however, it can affect the swallowing physiology of patients causing a significant malnutrition problem. Studies have also shown that as many as 7 to 9 out of 10 men had prostate cancer (PS) by age 80. Intensity modulation radiation therapy (IMRT) is an advanced and modern technique for efficient therapeutic treatment of cancer. The outcome of such treatments can be evaluated by assessing the dose volume histograms (DVHs) for various tumor targets and the critical structures in IMRT treatment plans. An in-house built software called *Histogram Analysis in Radiation Therapy* (**HART**, Jang et al, 2008, Med Phys 35, p 2812) was utilized for DVH assessments, plan based indices (PIs) evaluations, dose response polynomial modeling (POLYMODELs), and the radiation toxicity analysis for various critical organs (ORGANs) in the IMRT treatments.

Four different IMRT plans (PTV1, PTV2, PTV3 and COMPOSITE) at the respective prescription doses (PDs) range of 39-46 Gy, 10-15 Gy, 10-24 Gy, and 64-75 Gy were simulated in Pinnacle^3 treatment planning system for radiotherapy treatments of twenty HN patients at Northwestern Memorial Hospital. A retrospective study was also performed on eleven PS patients treated with radiation to a limited pelvic field with a standard 4 field arrangements at dose 45 Gy, and the sequential IMRT boosts field to a total isocenter dose of 75 Gy. Plans were simulated for a four field and three supplementary IMRT boosts with proposed dose delivery at 1.5 Gy/fraction in BID basis. The DVH parameters examined were mean PD, mean dose (DMEAN), maximum dose (DMAX) and the normalized volume (NVOLUME) covering a range of 93% to 120% of the PDs for each planning target volumes (ptv1,ptv2,ptv3) for HN and PS patients respectively. The NVOLUME covering 25%, 50%, 75% and 100% of the PDs for all ORGANs contoured in each plan were also evaluated for the radiation toxicity in the ORGANs. IMRT PIs analyzed were the dose conformality index (CI), homogeneity index (HI) and percent target coverage (PTC) at prescription isodose volumes (PDVs). Mean PIs were further statistically evaluated for HN patients (N=10) and PS patients (N=11) respectively. HART iteratively performed optimized POLYMODEL simulations of the cDVH curves for 26 structures (n=26) for the HN patients (N=20). Fano-Factor (FF) index was also used to scale the tissue inhomogeneity and the local constraint of the ORGANS using POLYMODEL simulations. The impacts of composite PD on tolerance dose (TD50) limitations on ORGAN complications were also analyzed for all patients (n=26; N=20).

Statistical means (HN; N=20) of DMEAN and DMAX distributions in all targets including composite volume were found to be (42.6, 14.3, 17.2, 69.5 Gy) and (45.6, 15.3, 18.4, 76.8 Gy) for PTV1, PTV2, PTV3 and COMPOSITE plans respectively. The mean PDs (HN; N=20) were estimated to be 41.0, 13.9, 16.9, and 71.8 Gy for the four plans respectively. Average NVOLUME (HN; N=20) above 93%, 95%, 105%, 110% of PD, were also found to be (0.98 ± 0.01), (0.97 ± 0.01), (0.37± 0.05) and 0 respectively for all targets. The 100% NVOLUME coverage of ORGANs were relatively irradiated with smaller doses. The mean HI (HN; N=10) was found to be 1.10, and mean PTC was evaluated to be 0.96 (HN;N=10) for all IMRT plans. The mean CIs (HN;N=10) for PTV1, PTV2, PTV3, and COMPOSITE plans were found to be 2.4, 2.4, 2.5, and 3.0 respectively. FF indices were evaluated to be of unit magnitude for POLYMODELs of all ORGANs (HN; N=20; n=26) at 95% confidence level data significance. Optimized POLYMODELs were relatively obtained at higher values of polynomial orders (HN;order >30; N=20; n=26) for 6 to 15 ORGANs and lower values of polynomial orders (HN;order < 10; N = 20; n = 26) for 8 to 12 ORGANs respectively. Gross Tumor Volume (FF=1) was used as the normalization unit of the relative tissue inhomogeneity and local constraint of the ORGANs. POLYMODELs were also used to extract the fractional volumes of the ORGANs at dose tolerance leading to 50% normal tissue complication probability (TD50) and at PD. Risk analysis of the seven beam segment based SqIB treatments revealed that a largest amount of the volume of submandibular gland (HN;99%; N=20; n=10) became irradiated at PD. However, parotid gland was found to be the most vulnerable structure with a volume coverage of 76±7 % (HN; N=20; n=10) at TD50 (46 Gy) and brainstem was found to be the least affected structure at TD50 (55 Gy) in the study.

A statistical analysis of dose coverage at planned targets in prostate gland and neighboring critical organs, and the PI evaluations were also performed using HART extracted DVH statistics. Statistical means (PS;N=11)

of DMEAN and DMAX distributions in all targets (PTV1,PTV2,PTV3) were found to be (13.2, 10.4, 6.6 Gy) and (13.9, 10.9, 6.9 Gy) for PTV1, PTV2, PTV3 plans respectively. The mean PDs (PS; N=11) were estimated to be 12.6, 10.4, and 5.1 Gy for the 3 plans respectively. Average NVOLUME (PS; N=11) above 95%, 100%, 110% of PD, were also found to be (0.98 ± 0.01), (0.43 ± 0.01), and 0 respectively for all targets. The 100% NVOLUME coverage of bladder and rectum were relatively irradiated with smaller doses (< 25% PD) in all 3 plans except 4 field pelvis plan. The mean HI (PS; N=11) was found to be 1.1±0.1, and mean PTC (PS; N=11) was evaluated to be 0.48 at PDs for all IMRT plans and 0.95 at 45 Gy PD for PELVIS plan respectively. The mean CIs (PS; N=11) for PTV1, PTV2, PTV3 plans were found to be 1.5, 1.7, and 2.3 respectively. The mean CNs (PS; N=11) for PTV1, PTV2, PTV3 plans were found to be 0.27, 0.27 and 0.24 respectively.

A better correlation of planning target volume coverage under 95% and 110% of PDs was achieved in both HN and PS cases for disease control. Critical structures were spared below their TD50. Mean HIs, CIs, PTCs for all plans were also found to be in good agreement with published results of 1.0 to 1.2 for HI, 3.0 for CI and 0.95 for PTC for linac based plans for both types of treatments. Mean HIs and CIs were relatively achieved in close agreement with standard results for IMRT plans in PS cases. We observed that polynomial techniques can also be efficiently used for evaluation of the relative inhomogeneity and the local constraint of the ORGANs at risk in a typical IMRT plan. The ORGANs with higher inhomogeneity and local constraint (FF>1) satisfied relatively higher order POLYMODEL (order >10) fittings. Thus the POLYMODEL techniques can also be efficiently and precisely used to determine the dose response models for various ORGANs in IMRT treatments. Analyzed results for PS patients also showed more reliable treatment outcomes (TCP, NTCP) due to smaller number of organs at risk in the treatment. In summary, we have demonstrated the efficiency, consistency and accuracy of the automated software, HART, in evaluation of the quality of IMRT plans and the dose response modeling of ORGANs utilizing precise DVH statistics extracted for large number of patients.