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Purpose/Objective(s)

To compare the uncertainties of 3D dose distributions, caused by the geometrical uncertainty of patient setup, in IMRT, VMAT, and proton plans for post-prostatectomy treatment. To test the effectiveness of a common margin recipe in these three types of treatment plans.

Material/Methods

Four prostate fossa patient datasets were included. For each case, three different plans were carried out: an IMRT plan of nine fields (XiO, Elekta), a VMAT plan, and a proton plan with two lateral active scanning beams (Oncentra, Nucletron). The plan robustness analysis function in CERR (Washington University, St. Louis, MO) software was used to simulate the DVH uncertainty with given systematic (Σ) and random (σ) shifts in three dimensions. Five different combinations of Σ (2-4mm) and σ (2-4mm) representing clinical situations were used for all plans. The DVH uncertainty range (upper and lower bounds) was generated by CERR for each setting of Σ and σ with a certain confidence level (95% was used in this study). We tested CTV coverage using a common margin recipe (2.5 Σ + 0.7 σ) for all IMRT, VMAT, and proton plans.

Results

More than 98% of PTV was covered by 95% of prescription dose in all plans. The upper bound of PTV $V_{95\%}$ was close to 100% in all plans for all Σ and σ settings. The mean values of lower bound of PTV $V_{95\%}$ were 85.4%, 85.0%, and 87.5% for IMRT, VMAT, and proton plans, respectively (p=0.03 for IMRT vs. proton, paired samples t-test; p=0.01 for VMAT vs. proton; p=0.36 for IMRT vs. VMAT). The mean values of ranges (upper minus lower bound) for rectum V_{45Gy} were 7.5% (IMRT), 7.5% (VMAT), 15.6% (proton), and the mean values of ranges for bladder V_{40Gy} were 6.2% (IMRT), 9.2% (VMAT), 12.7% (proton). The proton plans exhibited significantly wider range of rectum and bladder DVHs than the other two treatment techniques (p<0.05 for both). Even though the proton plans had lower rectum and bladder doses as compared with IMRT and VMAT, with the uncertainty, the upper bounds were approaching similar doses from IMRT and VMAT. Analysis of PTV V100%, rectum V_{56Gy}, bladder V_{56Gy} showed similar comparison results. The lower bound of CTV $V_{95\%}$ was larger than 99.4% in all plans with the estimated Σ and σ from the margin recipe, showing the effectiveness of the margin recipe for IMRT, VMAT, and proton plans included in this study.

Conclusion

In this simulation of potential setup uncertainties, larger variation in DVH for bladder and rectum were observed with proton plans than with IMRT and VMAT plans, to the extent that might compromise the advantage of proton plans. The common margin recipe was validated as a method to assure adequate target volume coverage for IMRT, VMAT and proton plans studied.