Dosimetric evaluation of treatment plans for a biology-guided radiotherapy system in treatment of nasopharyngeal cancer

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Purpose/Objective(s): This is an evaluation of a prototype treatment planning system (TPS) for a new biology-guided radiotherapy (BgRT) delivery system currently under development. The system combines a compact 6 MV linear accelerator and binary multileaf collimator with PET, kVCT, and MV imaging systems on the same ring gantry that rotates continuously at 60 rotations per minute while the patient is translated through the bore. We investigated the plan quality for treatment of nasopharyngeal patients without using PET guidance by comparing the plans with those using existing IMRT delivery techniques.

Materials/Methods: We retrospectively retrieved 5 clinical helical tomotherapy (HT) plans using a 2.5 cm jaw size and 3 clinical step-and-shoot IMRT plans with seven co-planar 6-MV fields that were used to treat nasopharyngeal patients according to the NRG-HN001 protocol, each with 3 or 4 PTVs at different prescription dose levels given in 33 equal fractions. A treatment plan (the prototype plan) using the prototype TPS was generated for each case, which models a binary delivery system that fires at 51 fixed gantry angles with each leaf fully opened or closed. Dose modulation is achieved with fast gantry rotation, couch moving in small increments, and each firing position being visited multiple times in the same axial plane. Volumetric modulated arc therapy (VMAT) plans using two coplanar 6 MV full arc fields were also generated for all 8 cases, where maximum sparing of organs at risk (OARs) rather than PTV dose homogeneity was emphasized during optimization. Paired t-tests were used to compare dosimetric parameters of PTVs and 21 OARs used in plan optimization.

Results: Each treatment plan achieved the required PTV dose coverage as in the protocol, with each PTV receiving at least 95% coverage by the corresponding prescription dose. Compared to the 3 step-and-shoot IMRT plans, the prototype plans gave lower dose to all the OARs, showing average reduction in the OAR dosimetric parameters in the range of -7.0% to -76.9%. Compared to the 5 HT plans, the prototype plans showed significantly higher dose heterogeneity to the PTVs, comparable maximum dose to the mandible, temporal lobes and brachial plexus, and lower dose to the other OARs with statistical significance. The VMAT plans achieved lower dose to some OARs with higher dose heterogeneity compared to the HT plans. Compared to the VMAT plans, the prototype plans had comparable PTV dose heterogeneity and comparable or lower dose to the OARs. The average mean dose to the parotid glands were 30.3±10.3 Gy, 22.3±4.7 Gy, and 18.8±2.9 Gy in the HT, VMAT, prototype plans, respectively.

Conclusion: Based on the beam modulation design of the BgRT delivery system, the prototype TPS could achieve sharp dose gradient outside the PTVs in radiotherapy plans for nasopharyngeal cancer patients with comparable or lower dose to a number of OARs compared to existing IMRT delivery techniques.