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Abstract
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Spatially Fractionated Lattice Radiotherapy Using Pencil-Beam Scanning Protons: A Treatment Planning Study

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Abstract

Objectives:

Protons have the potential to deliver spatially fractionated lattice radiotherapy (LRT) in a highly targeted manner with the added benefit of no exit dose. The intention of this work was to develop a standardized method to safely and effectively generate LRT treatment plans using pencil-beam scanning (PBS) protons for clinical implementation.

Methods:

Twelve (12) patients with bulky disease of either the head and neck, thorax, or pelvis/abdomen who were previously treated at our center with proton therapy were retrospectively planned using PBS protons to generate LRT treatment plans. For each patient, spherical vertices were placed throughout the gross tumor volume (GTV) with an inward margin of 1.0-1.5 cm. The dimensions and spacing of these vertices were determined using a reference table we developed to achieve similar GTV coverage and valley-to-peak dose ratios (VPDRs) as those described in photon LRT. The proton LRT plans were optimized using intensity-modulated proton-therapy (IMPT) along with a stereotactic radiosurgery-based planning technique to achieve a conformal single-fraction dose of 18 Gy (RBE = 1.1) to the vertices and 3 Gy to the GTV periphery, while maximizing sparing of nearby organs-at-risk. GTV dose-volume metrics, including D90%, D50%, D20%, D2%, Dmean, and VPDR (defined as the GTV D50:D2 ratio) were analyzed to identify reasonably achievable planning goals for proton LRT.

Results:

Proton LRT plans created with this technique showed consistent results across multiple treatment sites and a large range of target sizes, the average being 1017 mL (range 135–3546). The average vertex diameter, center-to-center spacing, and number of vertices used for planning were 1.5 cm (1.0-2.2), 3.7 cm (2.5-4.5), and 7.83 (3-17), respectively, with an average vertex to gross tumor volume (Vv:GTV) ratio of 1.55% (1.11-2.54). For GTV dose-volume metrics, the D90 = 309 cGy (SD=9), D50 = 433 cGy (SD= 104), D20 = 948 cGy (SD = 137), D2 = 1764 cGy (SD = 38), and Dmean = 628 cGy (SD=73). The average VPDR was 0.246 (SD=0.06), corresponding to a minimum valley dose of approximately 20-30% of the peak dose.

Conclusion(s):

The findings from this study demonstrate the feasibility of using PBS protons to generate conformal treatment plans that exhibit both high dose regions and low dose valleys characteristic of LRT. In addition, we developed a novel proton planning method that performed reliably and efficiently across multiple treatment sites and target sizes, which helped to standardize the planning process. Further studies investigating plan robustness and motion management, among other aspects of treatment, will help translate this work into clinical practice.