Rotationally Intensified Proton Lattice (RIPL): A Novel Method for Lattice Radiotherapy Utilizing Spot-Scanning Proton Arc

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Objective:
The aim of this study is to explore the feasibility and dosimetric advantage of utilizing a spot-scanning proton arc approach (SPArc) for lattice radiotherapy in comparison with volumetric modulated arc therapy (VMAT) and intensity modulated proton therapy (IMPT) lattice techniques.

Methods:
Lattice plans were generated for 12 large tumors across abdomen, pelvis, lung, extremity, and head-and-neck sites using VMAT, IMPT, and SPArc techniques. Lattice geometries were standardized and algorithmically generated. Vertices were 1.5 cm in diameter and arrayed in a body-centered cubic lattice with a 6 cm lattice constant. Vertices were clipped within 0.5 cm of the target border or 1.5 cm of a critical Organ-At-Risk (OAR). Prescription dose was 20 Gy(RBE) in 5 fractions to the periphery of the tumor, with a simultaneous integrated boost (SIB) of 66.7 Gy(RBE) to the vertices. OAR constraints per AAPM TG-101 were prioritized. Dose Volume Histograms (DVH) were extracted and used to identify maximum, minimum, and mean doses; equivalent uniform dose (EUD); D95%, D50%, D10%, D5%; V19Gy; peak-to-valley dose ratio (PVDR); and gradient index (GI). Treatment delivery time of IMPT and SPArc were simulated based on the published DynamicARC model.

Results:
Median tumor volume was 591 cc with a median of 5 high-dose vertices per plan. Low dose coverage was maintained in all plans (median V19Gy: SPArc 95%, IMPT 95%, VMAT 95%). SPArc generated significantly greater dose gradients as measured by median PVDR (SPArc 3.91, IMPT 3.62, VMAT 3.02; SPArc-IMPT p=0.0005, SPArc-VMAT p=0.002) and high-dose GI (SPArc 6.9, IMPT 10.8, VMAT 12.3; SPArc–IMPT p=0.0005, SPArc–VMAT p=0.002). There was no significant difference in simulated treatment delivery time between SPArc and IMPT (p=0.31). OAR constraints were met in all plans.

Conclusion:
SPArc therapy was able to achieve high-quality lattice plans for various sites with superior gradient metrics (PVDR and GI) when compared to VMAT and IMPT. Clinical implementation of RIPL is warranted.