Thoracic Spinal Cord FLASH SBRT Treatment Using a Single-Energy Proton Pristine Bragg Peak Delivery Technique

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Objectives: Treating a complex doughnut-shaped target with the spinal cord in the middle is challenging, even when using advanced proton pencil beam scanning (PBS). FLASH-RT may help to reduce the risk of complications for spine stereotactic body radiation therapy (SBRT), but the feasibility of using a single-energy proton pristine Bragg peak delivery technique to deliver conformal FLASH-RT to thoracic spine patients has not been studied. This study aims to examine the dosimetric and dose rate performance of this novel approach, termed Bragg peak FLASH (BP-FLASH), for thoracic spine SBRT.

Methods: Thoracic spine patients previously treated using conventional multiple-energy intensity-modulated proton therapy (CONV-IMPT) to 40 Gy in 5 fractions were re-optimized based on a in-house developed FLASH platform using the single-energy proton Bragg peak technique. BP-FLASH plans were designed with a similar beam arrangement to CONV-IMPT. The dose distributions and dose metrics were compared between the two techniques. The dose rate of the BP-FLASH plans was computed based on clinically proton machine parameters, including the max proton beam current, PBS spot delivery and scanning time. A quasi-mean dose rate calculation method averaged dose rate (ADR) was used to evaluate voxel-based 40Gy/s dose rate coverage (V40Gy/s) for OARs FLASH-sparing effect assessment.

Results: The dose coverage of BP-FLASH plans were normalized similarly to CONV-IMPT plans. All the dose metrics for major OARs, including spinal cord, esophagus, lung, and heart, were comparable between BP-FLASH and CONV-IMPT. The CTV Dmax was slightly higher in FLASH plans (BP-FLASH: 106.1% vs. CONV-IMPT: 102.2%) due to the absence of energy modulation for BP-FLASH compared to CONV-IMPT. The dose rate volume histograms (DRVHs) indicated that more than 50% of the volume of the OARs can reach a dose rate of at least 40Gy/s with no dose threshold applied, and 90% of the volume can reach a dose rate greater than 40Gy/s with a 2Gy dose threshold applied.

Conclusion(s): BP-FLASH plans can deliver highly conformal doses to the target while sparing the spinal cord, comparable to multiple-energy CONV-IMPT. Treating a complex doughnut-shaped target with a critical OAR inside using Bragg peak FLASH is feasible.