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An OAR Trace Method to Enable Highly Conformal FLASH Treatment for Proton Pristine Bragg Peak Delivery Technique

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Abstract

Objectives:

Single-energy Bragg Peak (SEBP) is a novel conformal proton FLASH technique that enables precise adaptation of the protons to the distal edge of the target by using beam-specific range compensators (RC) and universal range shifters (URS). Through multiple-field optimization (MFO), this technique can achieve plan quality comparable to conventional intensity-modulated proton therapy (IMPT), significantly outperforming transmission beam (TB) FLASH. This approach faces challenges in cases where OARs are surrounded by tumor target, as achieving OAR sparing while maintaining sufficient tumor coverage becomes more challenging. To address this problem, we propose a novel method combining target's distal tracking of the SEBP with OAR tracking to reduce the dose to OARs while simultaneously improving target coverage, thereby easing the challenge of balancing these two conflicting conditions during optimization.

Methods:

SEBP delivers doses to the target using distal tracking method, which shoots through the OARs inside of a Donough-shaped target. In our study, a raytracing algorithm was used to detect the boundaries of OAR contours. When the proton path passes through the target, crosses the OAR, and then reaches the distal edge of the target on the other side, the Bragg peak stops at the distal edge of the first section of the target that protons pass through, just before reaching the OARs, to avoid unnecessary exposure. The resulting dose deficit in the target on the other side is patched with another beam delivering radiation in the same manner. To evaluate this method, a phantom with a doughnut-shaped target and spinal cord tumor were employed to assess the dosimetric metrics of both distal tracking and OAR tracking plans. In this study, 3 beams (0, 90, and 270 degree) were used. The phantom plan was prescribed a single fraction of 8 Gy, Whereas the spinal cord tumor case followed a standard-of-care prescription of 15 Gy in one fraction in the context of stereotactic body radiation therapy (SBRT).

Results:

SEBP plans incorporating OAR tracking exhibited superior performance in reducing both mean and maximum doses to the OAR, as well as enhancing dose uniformity to the target, in both phantom and patient studies compared to regular SEBP plans. For instance, in the phantom study, the mean dose to the OAR was reduced by approximately 40%, and the maximum dose was decreased from 13 Gy to 8 Gy. Additionally, target dose uniformity improved by 20% .The mean dose of the spinal cord in the tumor was also significantly reduced with OAR tracking.

Conclusion(s):

By combining SEBP with OAR tracking, the potential FLASH sparing effect is maintained, while also resolving the conflicting objectives of enhancing target coverage and minimizing dose to OARs adjacent to the target. This approach demonstrates significant advantages in treating spinal tumors using proton FLASH.