Partial-volume proton-FLASH for a neurinoma case: single-layer approach to reduce delivery time

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Background and aims: Protontherapy plans offer lower overall doses compared to traditional radiotherapy but face challenges due to proton penumbra and range uncertainties near vital organs close to tumors. Balancing tumor coverage and organ protection can be challenging. The FLASH effect holds promise in minimizing damage to healthy tissues around the treatment area. However, its clinical implementation lacks agreement. Current research explores methods that might compromise the Bragg-Peak advantage or require patient-specific filters. Our objective is to devise a swift and practical approach for applying FLASH at the tumor-critical organ interface without compromising treatment efficiency.

Methods: We employed a newly developed multi-beam partial-volume FLASH method utilizing Raystation (Version 12A) for a previously treated neurinoma patient. During analysis of the clinical dose distributions, we found that ensuring adequate coverage of the CTV meant that the left cochlea (Cochlea_L) would unavoidably be irradiated at high doses. We focused on determining the optimal beam angle and single energy layer, without a filter, to achieve the most effective dose delivery to the CTV area adjacent to the Cochlea_L. Subsequently, the remaining CTV received irradiation using the same IMPT beams as in the clinical plan. This treatment plan (FLASH) was designed for delivery via a ProteusOne IBA machine, incorporating one FLASH beam per fraction (1×12Gy) and robustly optimized to account for positional and range uncertainties. The FLASH plan with no correction was compared to the equivalent clinically applied plan (CLIN) and FLASH plan with a dose-modifying factor of 0.8 (FLASH-DMF).

Results: CTV coverage is 97 % at 12 Gy, above the clinical requirement; CTV conformity index is 0.61 and homogeneity index is 0.71 (CLIN 0.69 and 0.92, respectively), see figure 1. Mean dose for Cochlea_L CLIN is 11.8 Gy and for FLASH is 11.1 Gy, further reduced to 10.3 Gy in the FLASH-DMF.

Conclusions: The proposed technique demonstrates that a simple approach to FLASH is possible, with adequate coverage and ensuring robust coverage. The technical difficulty to cover large volumes with a high dose rate can be solved with a partial volume FLASH irradiation.

Keywords: treatment planning, FLASH, Conformal FLASH, proton, TPS

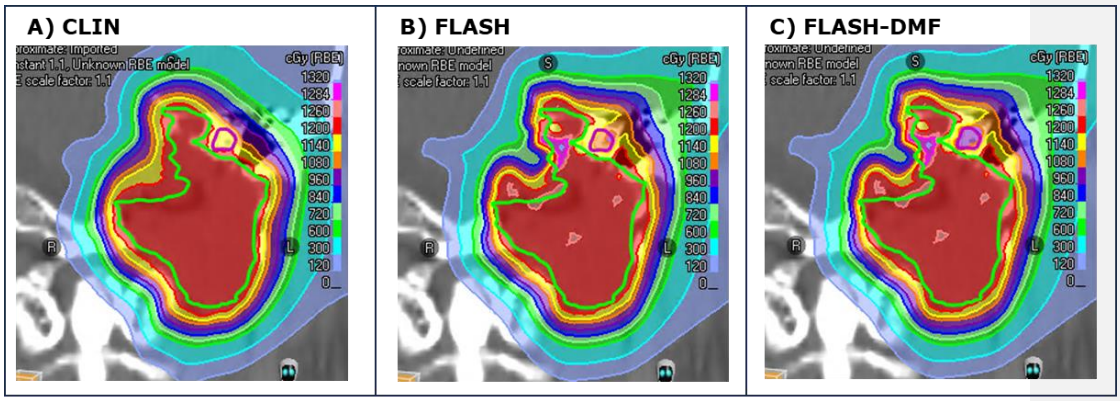

Figure 1. *– Studied dose distributions for clinical target volume (CTV, green), left cochlea (Cochlea_L, pink) and brainstem (orange). A) RBE-1.1 dose distribution for the clinically applied plan (CLIN). B) RBE-1.1 dose distribution for the FLASH plan. C) RBE-1.1 and FLASH effect dose modified distribution of the FLASH plan, by applying a Dose Modifying Factor (DMF) of 1.25 to the RBE-1.1 if the dose from the FLASH beam is above 5 Gy (FLASH-DMF) in the Cochlea_L.*