Spring 2022

The First Modeling of the Spot-Scanning Proton Arc(SPArc) Delivery Sequence and Investigating its Efficiency Improvement

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Recommended Citation

Ding X, Liu G, Zhao L, Deraniyagala R, Stevens C, Yan D, Li X. The first modeling of the spot-scanning proton arc (SPArc) delivery sequence and investigating its efficiency improvement. Int J Part Ther. 2022 Spring;8(4):97.

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PTCNA-0056

Assessment of shielding requirements for proton beam FLASH delivery

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Purpose: To evaluate the effectiveness of existing shielding in a dedicated research room (second floor) for proton FLASH beam delivery.

Materials and Method: The radiation survey was performed with Ludlum 42-38 WENDY-2 neutron detector and Ludlum 9DP ion chamber survey meter in a fixed horizontal beam room using an ultra-high dose rate proton beam (FLASH). A 250 MeV spot was delivered (total 5 minutes) with a cyclotron current of 600 nA (~210 nA at the nozzle), which provided a spot peak dose rate of 805 Gy/s. The survey meters were moved around to identify the highest reading of each location, and the readers were compared to survey results of clinical standard-dose rate beams.

Results: The highest readings for the FLASH beam were along the beam path and read 550 μR/hour on WENDY-2 and 55 μR/hour on 9DP ion chamber meter. The neutron and photon readings are 97 to 170 fold higher than for clinical beams for the location with direct transmission. The readings are ~28 fold higher in the control room due to the length of the maze. High activation of 650 mR/hour, 434 mR/hour, and 186 mR/hour was observed in the solid water beam stopper at isocenter 5, 30, and 60 minutes after FLASH delivery.

Conclusion: No extra shielding is needed to deliver FLASH beam in our research room. A beam-angle-dependent survey is recommended for the gantry room due to the flexible beam angles. Special attention should be paid to the activation of equipment in the treatment room.

PTCNA-0066

The First Modeling of the Spot-Scanning Proton Arc(SPArc) Delivery Sequence and Investigating Its Efficiency Improvement

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Purpose: Introduce an experimental approach to model a precise prototype arc system and quantitatively assess its efficiency improvement in the routine proton clinical operation.

Methods: The SPArc delivery sequence model(DSM_{SPArc}) includes two kinds of parameters:(1) mechanical parameters. (2) irradiation parameters. Log files and an independent gantry inclinometer were used to derive the irradiation parameters through a series of test plans. The in-house DSM_{SPArc} was established by fitting both mechanical and irradiation parameters. Eight SPArc plans from different disease sites were used to validate the model's accuracy. To assess the treatment efficiency improvement, the DSM_{SPArc} was used to simulate the SPArc treatment delivery sequence and compared to the clinical IMPT treatment logfiles from the two full clinical days.

Results: The relative difference of treatment time between log files and DSM_{SPArc}'s prediction was 6.1%±3.9% on average, and the gantry angle vs. delivery time showed a good agreement between the DSM_{SPArc} and log file (Figure 1). Additionally, the SPArc plan could effectively save two hours out of ten hours of clinical operation by simplifying the treatment workflow for a single room proton therapy center. The average treatment delivery time (including gantry rotation and irradiation) per patient was reduced to 226±149s using SPArc compared to 665±407s using IMPT ($p<0.01$).

Conclusion: SPArc can offer a superior delivery efficiency to improve daily patient treatment throughput, compared to IMPT. Most importantly, this model helps the community to further develop and investigate this merging technqieu especially incorporating the arc delivery speed and time into the SPArc optimization algorithm.