Further evidence: Pulse-by-pulse ultra-high resolution scintillation imaging of proton FLASH beams produced by a gantry-mounted synchrocyclotron

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Objective . Radiation therapy at ultra-high dose rate (UHDR) has emerged in the past decade as a novel technique with potential to improve the therapeutic index through a phenomenon referred to as 'FLASH effect'. Its reliable pre-clinical studies and safe clinical deployment would benefit from dosimeters with high spatiotemporal resolution, ideally with capability to perform pulse-by-pulse dosimetry for pulsed beams. Scintillation imaging has shown potential for high spatiotemporal resolution dosimetry that may be well-suited for UHDR beams. Our aim is to develop an ultra-high resolution scintillation imaging dosimetry system for characterization of pulsed UHDR proton beams on a pulse-by-pulse basis. Approach. A gantry-mounted proton therapy synchrocyclotron was used to deliver UHDR beams at ?90 Gy s -1 average dose rate. A BC-408 plastic scintillator block (30 × 30 × 5 cm 3), facing a high-speed camera inside an optically sealed housing, was used for range, relative dose-per-pulse, vertical spot position, Bragg peak (BP) widths, and beam size measurements. Another BC-408 plastic scintillator block (30 × 30 × 0.5 cm 3), facing a mirror at 45°, was used to measure the spots' lateral size and position. A high-speed complementary metal-oxide-semiconductor camera system, temporally gated with the accelerator's pulse train, was used for imaging. Series of proton pulses with different ranges were delivered at various dose rates per pulse while the corresponding scintillation images were recorded to extract various beam parameters. Results. Individual image frames corresponding to each delivered pulse were successfully obtained at ?0.08 mm per-pixel resolution. The integrated image intensity at the BP showed a linear correlation with the delivered charge-per-pulse. The scintillation signal agreed with the charge reading from the transmission ionization chamber within 1%. Our measurements did not demonstrate appreciable dose rate dependency of the ionization quenching in the scintillator. Range measurements on a pulse-by-pulse basis agreed within 1 mm of the programmed range and were confirmed with a multi-layer ionization chamber device. Spot sizes were measured within 0.3 mm of the expected values. Significance. Synchronized scintillation imaging can provide ultra-high spatiotemporal resolution dosimetry of pulsed UHDR proton beams desired for beam characterization. A strong correlation between measured scintillation intensity and beam current suggests that our system can be expanded for quantitative multidimensional dosimetry.

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