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A Novel Ultra-High Dose Rate Proton Therapy Technology: Spot-Scanning Proton Arc therapy FLASH (SPLASH)

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MEDICAL PHYSICS

Purpose: A small animal irradiator that can deliver FLASH-RT treatments similar to clinical RT treatments is needed for preclinical studies of FLASH-RT. We designed and optimized a novel small animal FLASH irradiator (SAFI) based on the distributed x-ray technology**. Methods:** The SAFI system comprises a distributed x-ray source with 51 focal spots equally distributed on a 20 cm diameter ring, which are used for both FLASH-RT and inverse-geometry micro-CT imaging. In FLASH-RT mode, a custom-designed multi-aperture collimator (MAC) is positioned in the beam path, and all sources are activated simultaneously according the treatment plan. In imaging mode, the MAC is replaced with a small area detector and another imaging MAC that rotate about the animal together while the x-ray sources within the field-of-view are activated sequentially at each projection angle. Monte Carlo simulation was performed to characterize the dosimetric characteristics of the SAFI treatment beams. The system parameters necessary to achieve UHDR, including geometry, kVp, tube current, focal spot size, and beam-on duration, were determined. Inverse-geometry micro-CT acquisition was simulated, and the images were reconstructed using an iterative reconstruction algorithm**. Results:** At 160 kVp, with 51 focal spots each in the dimension of 2×20 mm^2 and 10° anode angle, the SAFI system can produce up to 120 Gy/s maximum continuous (DC) irradiation at the center of a 4 cm cylindrical water phantom. The system can also deliver FLASH-RT in pulse mode with a greater instantaneous dose rate. The maximum doses that can be delivered in each pulse at different dose rates were determined using finite element thermal analysis. We further demonstrated forward and inverse FLASH-RT planning, as well as inverse-geometry micro-CT via numerical simulations**. Conclusion:** The SAFI with integrated inverse-geometry micro-CT is capable of delivering conformal FLASH-RT to small animals.

WE-D-BRA-03, A Novel Ultra-High Dose Rate Proton Therapy Technology: Spot-Scanning Proton Arc therapy FLASH (SPLASH): G Liu[1, 2]*, L Zhao[2], X Li[2], S Zhang[1], S Dai[3], X Lu[3], X Ding[2],(1) Cancer Center, Union Hospital, Tongji Medical College, Huazhong University, China, (2) Beaumont Proton Center, Royal Oak, MI, (3) Beaumont Health System, Royal Oak, MI, USA (3) School Of Mathematics And Statistics, Wuhan University, China

Purpose: The flash dose rate on the order of 40 Gy/s has the potential to spare normal tissue with iso-effective tumor growth delay. Meanwhile, the spot-scanning proton arc therapy(SPArc), demonstrated its superior dosimetric conformity and plan robustness compared to the conventional intensity modulated proton therapy(IMPT). To take the full advantage of flash dose rate and the high dose conformity, we introduce a novel optimization and delivery technique, SPArc FLASH (SPLASH)**. Methods:** SPLASH framework was implemented in an open-source proton planning platform (matRad). It optimizes the spot moniter unit(MU) weighting and cyclotron beam current per spot simultaneously. More specifically, it simultaneously optimized with the clinical dose-volume constraint based on dose distribution and optimized the dose-average dose rate by minimizing the monitor unit constraint on spot weight and maximum cyclotron beam current to minimize the cost function value combined by dose and dose rate. A intracranial target (volume = 20.8cc) case was used for testing purpose. Prescription is 50 Gy in 25 fractions. Dose-volume histogram, dose averaged dose rate histogram and dose rate map per spot were compared between SPArc and SPLASH**. Results:** The dose-averaged dose rate histogram indicated that flash dose rate (40Gy/s) could not be achieved using the original SPArc with the current clinical beam current configuration. With a same plan quality, SPLASH improved dose-averaged dose rate of Vr>40Gy/s in PTV, optic chiasm, optic nerve and brainstem from 0%, 0%, 0%, 0% in SPArc plan to 100%,100%,100%,75%, respectively. The optimal cyclotron beam current per spot is simultaneously generated**. Conclusion:** The SPLASH offers simultaneously optimizing dose distribution and dose rate. It could generate a treatment plan with a superior conformal dose distribution and ultra-high dose rate, which has never been demonstrated before.

WE-D-BRA-04, Calibration and Validation of a Real-Time Oximeter for FLASH-RT Experiments: K Liang*, G Pratx, R Manjappa, B Ha, C Liu, S Melemenidis, J Rao, B Loo, Stanford University, Stanford, CA

Purpose: To develop real-time optical oximetry under FLASH radiotherapy (FLASH-RT) and conventional radiotherapy, and further understand the normal tissue-sparing effect of FLASH-RT**. Methods:** An epifluorescent laser system was constructed to measure the kinetics of O_2 depletion during FLASH-RT with high temporal resolution. A 1 kHz 640 nm laser excites air-tight samples of PBS buffer containing a soluble oxygen-sensitive phosphorescent nanoprobe and various concentrations of oxygen. The same optic fibre detects the 794 nm phosphorescent decay of the nanoprobe. The decay lifetime is calculated by averaging the decays of several pulses, and fitting the data to a dual-exponential function. Calibration measurements with unirradiated samples ranging from 0-100 μM [O] are used to determine the relationship between [O] and probe lifetime (via a Stern-Volmer plot). Validation of this method includes comparing the calculated and known [O] of the calibration samples. Approximately 20 Gy of CONV-RT and FLASH-RT are then repeatedly delivered to separate samples to detect the change in oxygen concentration**. Results:** Examination of [O_2] under CONV-RT exhibited a linear decrease in concentration over time during irradiation. The measured O_2 depletion yield agrees with previous measurements made using a polarographic electrode. Under

