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A Cabinet X-ray Platform with Robotic Scanning for Pre-clinical FLASH-RT and SFRT Research

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Objectives

FLASH RT and Spatial Fractionated (SF)RT exhibit transformative potentials by leveraging respective temporal and spatial factors beyond the confines of conformal RT. Non-uniform dose and dose rate are issues in their deliveries of conformal FLASH RT and GRID/LATTICE with scanning particle beams. For SFRT, the difference in curative and palliative endpoints between laboratory and clinical studies further confound clinical translation.

Effective translations of FLASH and SFRT necessarily require pre-clinical studies at high dose rate and high spatial (~0.5 mm) resolution. Kilovoltage (kV) x-rays offer advantageous localized energy deposition. Unfortunately, other than one specialized Synchrotron x-ray source for high resolution SFRT research, single kV x-ray source is significantly hampered by the much-reduced dose rate, and significant degradation of peak (P) and valley (V) dose parameters at short SSD. The challenge compels our development of x-ray cabinet system to support systematic preclinical FLASH and SFRT research.

Methods

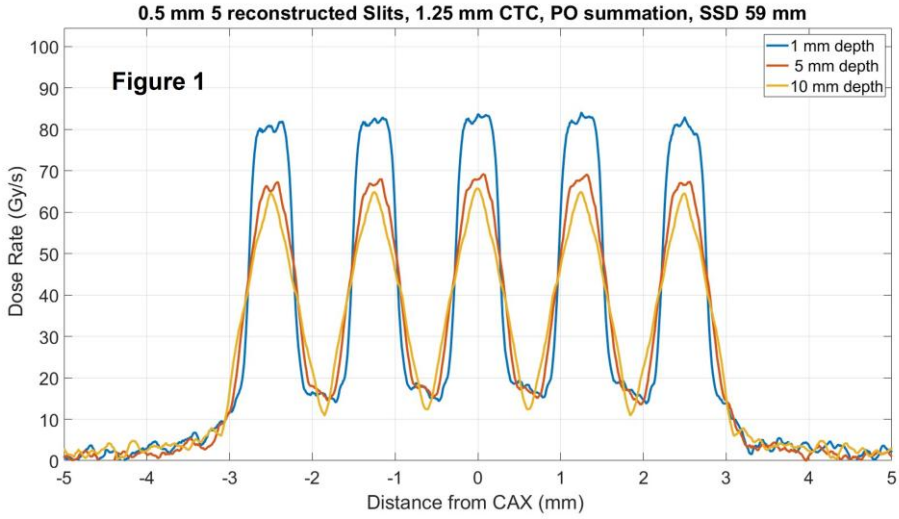
A pair of mirrored parallel-opposed (PO) 150 kVp fluoroscopic x-ray sources are positioned 140 mm apart to achieve FLASH dose rates in a mouse-size subject while maintaining uniformity in depth and cross beam dose profiles. A study subject is robotically “scanned” a with micrometer resolution under a stationary PO 0.5 mm slit beam to enable the delivery of a wide range of PV dose and spacing parameters.

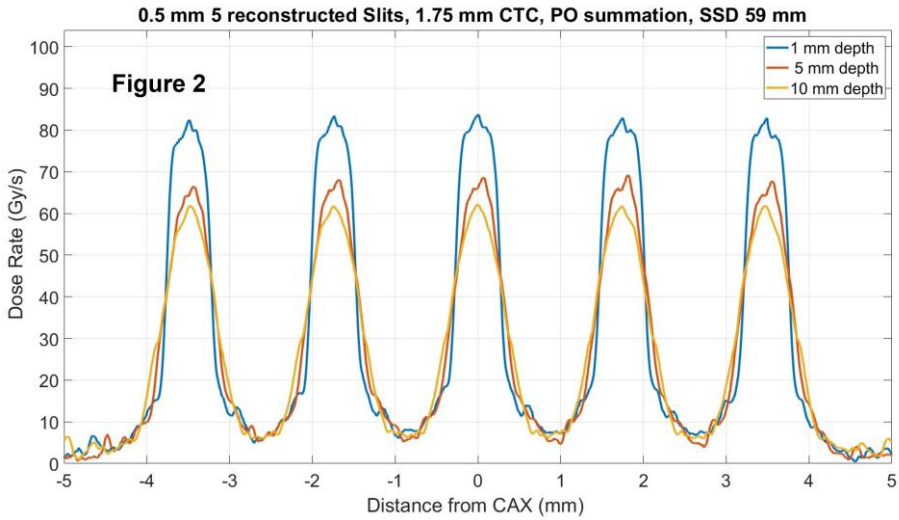
Results

At mid-10 mm in a 20 mm thick mouse-size phantom, the PO 0.5 mm slit can be accurately aligned to deliver 25 Gy in < 0.5 s. Uniformity of the adjustable P and V doses, and PV dose ratios, are maintained to within +5% for depths from 5 mm to 15 mm to mimic a shoot-through proton beam. An area of 10x10 mm2 can be irradiated in <100 sec with a single scanning PO 0.5 mm slit. Figures 1 and 2 show the uniform dose distributions of five PO 0.5 mm slits, reconstructed from the measured data of a single PO slit, at center-to-center spacing of 1.25 mm and 1. 75 mm apart, respectively, for d= 0, 5, 10 mm.

Conclusions

High resolution SFRT irradiation can be conducted at FLASH dose rate in a x-ray cabinet system. Robotic scanning allows efficient PV modulation for systematic mechanistic studies. With high heat capacity sources, a single PO slit supports SFRT irradiation of > 25 mice a day, and inform the use of 2-3 PO slits for large cohort study of >50 mice a day.


0.5 mm 5 reconstructed Slits, 1.25 mm CTC, PO summation, SSD 59 mm
Figure 1
1 mm depth
5 mm depth
10 mm depth
Dose Rate (Gy/s)
Distance from CAX (mm)


0.5 mm 5 reconstructed Slits, 1.75 mm CTC, PO summation, SSD 59 mm
Figure 2
1 mm depth
5 mm depth
10 mm depth
Dose Rate (Gy/s)
Distance from CAX (mm)