Efficient image-guided rodent irradiations on high-throughput eFLASH platforms

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Cost-effectiveness and throughput are crucial factors that contribute to the widespread use of rodents in translational radiation sciences. However, most existing ultra-high dose rate (UHDR) electron irradiators produce non-uniform UHDR beams, restricting the execution of in vivo studies in several ways; including limiting the number of animals that can be irradiated with a single beam delivery to one. Furthermore, there is a need for further exploration into image-guidance tools for accurate targeting in small animal UHDR irradiations.

Leveraging uniquely wide (~14 cm diameter) and uniform fields on our FLASH-enabled Varian Clinac 21-EX, which has otherwise identical conventional (CONV) and UHDR (up to 130 $Gy.s^{-1}$) beams, we have developed and commissioned high-throughput workflows for accurate and precisely-targeted eFLASH irradiations of rodents. Using in-house designed collimators, we have commissioned platforms for eFLASH irradiations of up to 4 rat prostates, 4 single mouse lungs, 3 mouse whole-lungs, or 5 flank tumors in mice or rats per beam delivery. The collimator apertures are tapered to follow beam divergence, sharpening the penumbrae and improving dose uniformity compared to unfocused apertures. Acrylic positioning templates enable parallelization of the irradiation workflow. Openings in the templates match the collimated fields while banked into place within a permanently affixed frame. On-board imaging on a neighboring (clinical, non-FLASH) linac is used for animal imaging and positioning on the templates. The collimator, which becomes radioactivated after UHDR exposures, remains set up on the FLASH-enabled linac and is allowed to decay for at least 10 minutes between runs.

Our eFLASH irradiation platforms are high-throughput and deliver comparable dose distributions to several rodents at a time. The broad UHDR beam also enables accurate dose and dose rate tuning via the source distance and MU settings. Efficient and accurate targeting of UHDR electrons in FLASH effect investigations is achieved with a parallelized workflow.

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