Anthropomorphic Mouse Phantoms and Accurate Small Animal Radiation Studies in Small Animal Cabinet Irradiators

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Purpose: Pre-clinical small animal irradiation studies, once commonly conducted on Cesium irradiators, are increasingly being performed using x-ray-based irradiators. The transition from Cesium sources to x-ray sources is driven in large part by concerns regarding national security risks, but this change also enables the use of compact, safe, and easily operated cabinet irradiators. However, questions regarding the relative biological effectiveness between the two sources has revealed a lack of adequate dosimetric characterization of x-ray beams and standardized protocols for dose calibration. The purpose of this study was to first characterize the cabinet irradiator system including the beam profile, HVL, percent depth dose curves, and the effects of temperature, pressure, and collimator size on dose given, and second, to determine whether in-air or in-water calibration techniques are more accurate for mouse studies.
Methods: The cabinet irradiator (XRAD 320, Precision X-Ray) was used at 320 kV, 12.5 mA, and 500 cGy. Dosimetric calibrations followed protocol established in AAMP TG-61 and used a calibrated farmer chamber (Exradin, A12) and calibrated electrometer (Keithley 614). Percent depth dose curves were generated with a thin window mylar chamber (Carpentec PS-033). A heterogenous phantom mouse was 3D-printed with inserts for radiochromic film (EBT-XD) and TLDs to be used. **Results:** Percent depth dose curves generated with a thoreaus filter (commonly used for animal studies), found d_{max} to be at 0.2cm. The ratios of dose at depth D=0 cm to D=2 cm was found to be 1.29 for 2mm Al filter and 1.17 for the thoraeus filter. The HVL for the beam when filtered with 2mm Al was 1.5mm Cu and when filtered with the thoraeus filter was 4mm Cu. For the thoreaus filter, in-air calibration protocols yielded higher dose to mice than in-water calibration protocols. Smaller field sizes delivered less dose than prescribed, and daily temperature and pressure fluctuations altered delivered dose up to ±3%. **Conclusions:** The in-air dose calibration methods typically recommended by small cabinet x-ray irradiator companies are adequate for approximating doses to thin samples sitting on the table, such as Petri dish cell studies. However, they deliver a higher dose to mice than anticipated.

Relevance to CIRMS: This research work has direct implications in radiobiology and pre-clinical studies that are relevant to medicine, with the overarching goal being to have more accurate dose delivery in small-animal radiation studies. This work has direct implications for national security as it advances the transition from cesium irradiators to x-ray irradiators. All in all, this work aligns with the missions of CIRMS to develop standard protocols for radiation used in medical settings and to advance national security initiatives pertinent to radiation.

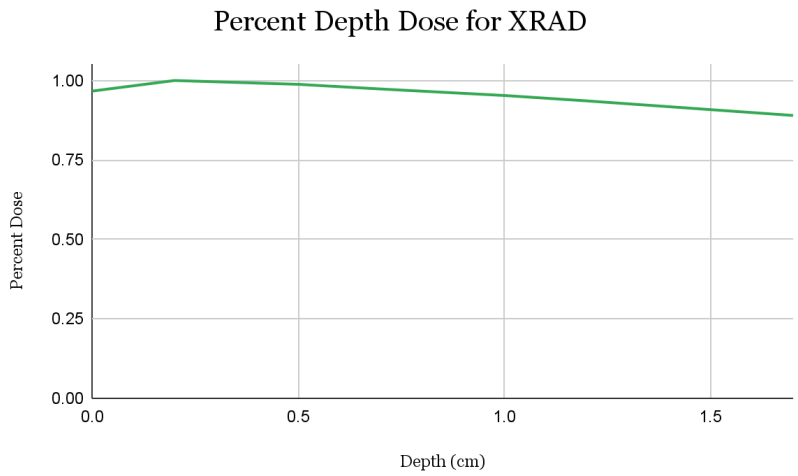

Figure 1: Percent depth dose curve generated with the thin window mylar chamber on the XRAD 320 (Precision X-Ray) with thoreaus filtration, indicating that there is a slight build-up of dose in a small animal when the thoreaus filter is used, with d_{max} = 2 cm.

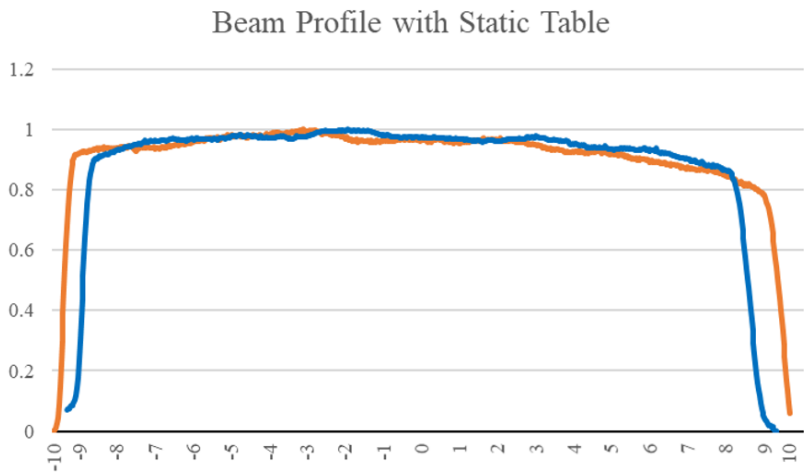

Figure 2: The profile of the beam in the horizontal direction for **Orange**: 20 cm field, and **Blue**: 18 cm field reveals an asymmetric beam with a heel effect, indicating the need for a rotating table during dose delivery to ensure equal dose distribution.