Development of a Murine Irradiation Platform for Screening of Medical Countermeasures against Multi-organ Injuries

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Purpose: This study demonstrates the development of an irradiation geometry to be utilized for the screening of countermeasures for gastrointestinal-acute radiation syndrome (GI-ARS) and radiation-induced pulmonary fibrosis (RIPF). ARS manifests as three different subsyndromes (hematopoietic, gastrointestinal, and cerebrovascular), each at increasing levels of absorbed dose. This work is based on a mouse model and requires irradiation to dose levels high enough to induce GI-ARS and RIPF, without the animal succumbing to hematopoietic(H)-ARS.

Methods: Irradiation was performed using a 4 MV photon beam from an Elekta Infinity clinical accelerator (LINAC). H-ARS effects were attenuated by sparing approximately 2.5% of the animal's bone marrow through the extension of one hind leg outside of the radiation field. This allowed for irradiation to the higher dose levels required to induce GI-ARS and RIPF. Dose mapping for this irradiation geometry was based on alanine electron paramagnetic resonance (EPR). Alanine pellet dosimeters were inserted into mouse phantoms at positions which correspond to the head, abdomen, and pelvis. Verification of dose accuracy and bone marrow sparing was performed through real-time ion chamber dosimetry measurements during mice irradiation, and a thermoluminescent dosimetry (TLD) intercomparison.

Results: The average dose rate determined by alanine-EPR dosimetry was 2.8 Gy/min. Field uniformity along the crossline direction was within 3% of the field center, and the width of the 80%-20% penumbra along the inline direction was 6 mm. Confirmation of the in-field (abdomen) and out-of-field (femur) doses was obtained through real-time ion chamber measurements taken during experimental irradiations of mice. Additional verification of the bone marrow sparing was performed through irradiation of thermoluminescent dosimeters (TLDs) embedded in a mouse phantom. This dosimetry intercomparison resulted in an in-field dose within 5% that was determined using alanine, and an out-of-field dose that was 23% that of the in-field dose.

Conclusions: This study demonstrates how the precise delivery of dose from a LINAC can be applied to the partial-body irradiation of mice for countermeasure screening. Hematopoietic damage in this animal model was reduced to a level that enables investigation of GI and late stages of radiation-induced damage.

Disclaimer: The views expressed here are those of the authors and do not reflect the official policy of AFRRI, USUHS, DoD or the US Government. Neither I nor my family members have a financial interest in the product, service, or organization providing financial support for this research. Funding for this work was from NIAID-IAA and AFRRI Intramural funds to Dr. Vidya P. Kumar.