Dose Rate Determination for Preclinical Total Body Irradiation

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INTRODUCTION

- The accuracy of delivered radiation dose of radiotherapy methods are key factors for preclinical radiobiology applications and research studies.
- Large dose discrepancies are seen in publications due to lacking dosimetry details related to irradiation protocols.
- This work exemplifies the accurate determination of the dose rate for total body irradiation (TBI), a classic radiobiologic and immunologic experimental method.
- Our study demonstrates that physics expertise and consultation are crucial for accurate dose delivery in preclinical studies.

METHOD

❖ Experimental measurements:

Precision X-rays XRAD 320 platform, HVL=0.45 mm Cu,250kVp.

PTW UNIDOS E electrometer and N31010 ionization chamber

calibration at SSD=65 cm, measurements at 63.5cm

TG-61 protocol

$$\dot{D}_{w,z=1.5} = MN_K B_W P_{stem,air} \left[\left(\frac{\bar{\mu}_{en}}{\rho}\right)^{w}_{air}\right]_{air} * \left(\frac{SSD_{cal}}{SSD}\right)^2 * PDD(1.5)/100$$

❖ Monte Carlo simulation with the same setups

❖ Phantom and geometry

Phantoms and the geometries shown in Fig. 1

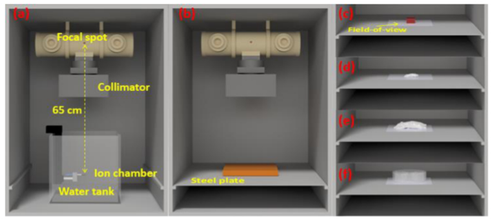

Fig. 1. The configurations used for dose measurements. a) In-air calibration setup; b) the solid water phantom; c) the small water box phantom; d) the silicon rubber mouse phantom; e) the silicon rubber rat phantom; and f) the mouse pie cage. Fully opened collimator with the maximum irradiation field, 26.4 × 26.4 cm^2, projected on the steel plate at a 65 cm focal spot distance.

RESULTS

➢ The Monte Carlo simulated dose rates ($\dot{D}_{w,MC}$) and the measured dose rates ($\dot{D}_{w,IC}$) show favorable agreement, as seen in Table 2. On average, the relative dose rate difference was 2.3%.

➢ Large deviations present when comparing the dose rates to the hand calculations based on lookup tables and the commonly used reference calibration dose rate.

➢ In a TBI setting, the reference calibration geometry at an extended source-to-surface distance and a large reference field size is likely to overestimate true photon scatter: 16% for a large solid water slab, 27% for a small water box, and 31%, 36%, and 30% for mouse phantom, rat phantom, and mouse phantom in a pie cage, respectively, shown in Table 3.

Table 2. Measured ($\dot{D}_{w,IC}$) and MC simulation ($\dot{D}_{w,MC}$) dose rate results in different phantoms.

IC & MC	Setup Description	SSD [cm]	Measurement depth [cm]	$\dot{D}_{w,IC}$ [Gy/min]	$\dot{D}_{w,MC}$ [Gy/min]	e [%]
IC-1 & MC-1	In-air calibration	65.0 FSD	NA	1.537	1.537	0.0 (by definition)
IC-2 & MC-2	Solid water phantom	62.0	1.5	1.314	1.349	2.6
IC-3 & MC-3	Small water box	62.0	1.5	1.155	1.166	0.9
IC-4 & MC-4	Mouse phantom	62.9	1.05	1.070	1.106	3.3
IC-5 & MC-5	Rat phantom	61.5	1.75	0.976	1.014	3.9
IC-6 & MC-6	Mouse phantom in a pie cage	62.0	1.05	1.105	1.114	0.8

Table 3. Relative dose rate differences calculated using the point dose hand calculation method compared to the ionization chamber measurements and Monte Carlo simulations.

IC & MC	Setup Description	$\Delta\dot{D}_{IC}$ [%]	$\Delta\dot{D}_{MC}$ [%]	$\frac{1}{2}[\Delta\dot{D}_{IC} + \Delta\dot{D}_{MC}]$ [%]
IC-2 & MC-2	Solid water phantom	15.0	16.7	15.9
IC-3 & MC-3	Small water box	25.3	28.0	26.7
IC-4 & MC-4	Mouse phantom	30.8	31.7	31.3
IC-5 & MC-5	Rat phantom	36.9	36.0	36.5
IC-6 & MC-6	Mouse phantom in a pie cage	28.5	31.2	29.9

CONCLUSIONS

❑ Small changes in TBI experimental setup could result in large dose rate variations.

❑ MC simulations and the corresponding measurements specific to a designed experimental setup are vital for accurate preclinical dosimetry and reproducibility of radiobiological findings.

❑ Physics consultation is highly recommended for all radiobiological investigations.

REFERENCES

1. Ma CM, Coffey CW, DeWerd LA, Liu C, Nath R, Seltzer SM, Seuntjens JP: **AAPM protocol for 40-300 kV x-ray beam dosimetry in radiotherapy and radiobiology**. *Med Phys* 2001, **28**(6):868-893.
2. Jia X, Gu X, Graves YJ, Folkerts M, Jiang SB: **GPU-based fast Monte Carlo simulation for radiotherapy dose calculation**. *Phys Med Biol* 2011, **56**(22):7017-7031.
3. Gronberg MP, Tailor RC, Smith SA, Kry SF, Followill DS, Stojadinovic S, Niedzielski JS, Lindsay PE, Krishnan S, Aguirre F: **A Mail Audit Independent Peer Review System for Dosimetry Verification of a Small Animal Irradiator**. *Radiation Research* 2020.

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