# The Effect of Mouse Size on Dose Delivered to Mouse-Like Phantoms from an X-Rad 320 Irradiator

JOHN T. STASKO, CLIFFORD G. HAMMER, AND WESLEY S. CULBERSON

Department of Medical Physics, School of Medicine and Public Health, University of Wisconsin-Madison

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## INTRODUCTION

The X-Rad 320 biological irradiator (Precision X-Ray Inc., North Branford, CT) is a cabinet x-ray irradiator commonly used for whole-body irradiation of mice. Irradiation protocols for this machine often ignore individual variation between mice, opting for a standardized dose rate estimate [1].

**The goal of this work is to use 3D-printed mouse-like phantoms to test the effect of mouse size on dose rates delivered by the X-Rad 320 irradiator.**

## PHANTOM DEVELOPMENT

**Mouse Phantom Design:**

Five phantoms of varying size were modelled in SolidWorks 2018 (Dassault Systèmes SolidWorks Corporation, Waltham, MA) in order to be 3D-printed. The relative sizing of the phantoms was based on the mouse whole-body (MOBY) model [2]. A simple geometric design was used to ensure the phantoms could be easily scaled. The volume of the five phantoms are 22.13 cm$^3$, 24.95 cm$^3$, 27.80 cm$^3$, 30.51 cm$^3$, and 33.25 cm$^3$.

**3D-Printing:**

A Form 2 3D-printer (Formlabs Inc., Somerville, MA) was used to print the five phantoms. All mice were printed from tail to head in 25 µm thick slices. Included in each print was a cylindrical holder designed to slot into the back of each phantom and hold three thermoluminescent dosimeters (TLD) microcubes in one rectangular slot. The holder was designed to position the TLD microcubes in the center of the phantom's abdomen-like area, midway between the top and bottom surface of the phantom. After printing, each phantom was placed in an isopropyl alcohol bath and agitated for 20 minutes to remove any excess liquid resin. The phantoms were then set in a UV curing machine for one hour. **Figure 1** shows one completed phantom and its corresponding TLD holder. **Figure 2** highlights how the TLD holder is used with the phantom.

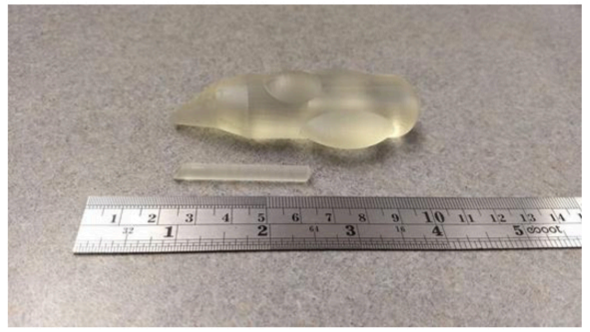

**Figure 1.** The 27.80 cm$^3$ phantom and its corresponding TLD holder used in this project.

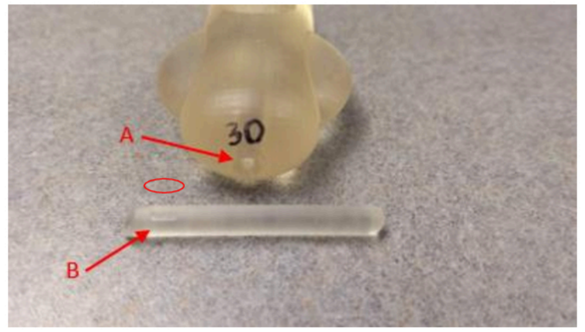


**Figure 2.** View of the back of the 27.80 cm$^3$ phantom. (A) indicates where the TLD holder is inserted. (B) shows where the three TLD microcubes are placed in the holder.

## IRRADIATION PREPARATION AND DELIVERY

**TLD Preparation and Calibration:**

TLD microcubes (Thermo Fisher Scientific, Oakwood Village, OH) were annealed following the protocol described by Nunn et al. [3]. Each microcube received a 5 R exposure from $^{137}$Cs followed by the annealing protocol. This was done three times, and all microcubes were evaluated for reproducibility of their resulting signal. In the end, only dosimeters with a signal standard deviation of less than 2% were selected for use in this study.

**Irradiation:**

For each X-Rad 320 irradiation, the tube potential was 320 kVp, and the time-current product was 812.5 mAs. In addition, a filter composed of 1.5 mm Al, 0.25 mm Cu, and 0.75 Sn was placed in the beam. This filter is the most commonly used filter in the facility where this research took place. The phantoms were placed on the surface of a polycarbonate slab positioned at 50 cm from the photon source. The field size at the surface of the slab was 20 x 20 cm$^2$. Each phantom held three TLD microcubes per irradiation with the central TLD in each phantom positioned along the central axis of the beam. The irradiations were performed five times for each phantom. **Figure 3** shows the experimental setup, and **Table 1** displays some physical properties of each phantom.

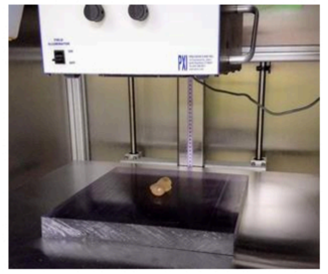

**Figure 3.** Photograph showing a phantom on top of the polycarbonate slab inside the X-Rad 320.

| Volume (cm$^3$) | TLD Depth (cm) | Source to TLD (cm) |
|---|---|---|
| 22.13 | 0.880 | 49.120 |
| 24.95 | 0.916 | 49.084 |
| 27.80 | 0.950 | 49.050 |
| 30.51 | 0.980 | 49.020 |
| 33.25 | 1.009 | 48.991 |

**Table 1.** Some relevant physical parameters for each phantom. TLD Depth describes the distance from the upper surface of the phantom to the center of the TLD microcubes along the central axis of the beam

## RESULTS

Glow curves for each irradiated TLD were created using the method described by Nunn et al. [3]. The average reading of the TLD microcubes from each phantom was used to calculate an output factor (OF) for that phantom. The OF was calculated relative to the signal from the phantom of median volume. The OF for the reference phantom is defined to be 1.0.

The relative standard uncertainty (k=1) shown in **Figure 4** is a function of the standard deviation of the TLD microcube signals, positioning uncertainty of the TLD microcubes inside the phantoms (0.15%), and nonlinearity in the signal readout from the photomultiplier tube (0.10%), summed in quadrature.

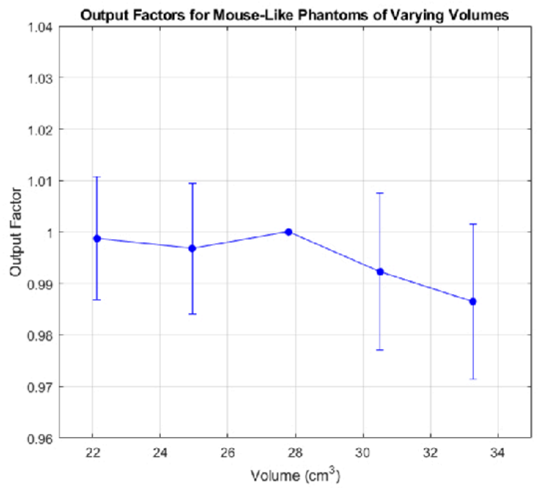


**Figure 4.** Output factors for the five mouse-like phantoms. Error bars indicate the relative standard uncertainty (k=1).

## CONCLUSION

The OFs varied between 0.987 and 1.000 among the phantoms with volumes between 22.13 cm$^3$ and 33.25 cm$^3$. **All OFs were within relative standard uncertainty (k=1) of unity, suggesting that the relative dose rate to the abdomen of the mouse-like phantoms does not vary significantly with the phantom size.** This is encouraging for radiobiologists who wish to compare results between various studies involving the X-Rad 320 with different mouse sizes. It is important to note that this research focused on sizes typical of adult mice identified by Keenan et al. [2].

The slight decrease in OF for the larger phantoms may indicate that the increased attenuation from their larger abdomens is the main factor driving the change in OF. Future research involving Monte Carlo simulations may help quantify the relative effects of scatter, distance from source, and attenuation in the phantoms. Additionally, these simulations will make it possible to examine changes in the dose distribution at any point inside the phantoms.

## REFERENCES

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## CONTACT INFORMATION

Please contact John Stasko at jstasko@wisc.edu with any questions