



# Multi-Source Conformal Superficial Brachytherapy: A Dose Escalation Study

B Rogers<sup>1\*</sup>, J Lawrence<sup>2,3</sup>, C Ferreira<sup>1</sup>

(1) Department of Radiation Oncology, University of Minnesota - Twin Cities, Minneapolis, MN

(2) Department of Veterinary Clinical Sciences, University of Minnesota, Saint Paul, MN

(3) Masonic Cancer Center, University of Minnesota, Minneapolis MN

## INTRODUCTION

The mechanisms of radiation-induced skin damage are similar between mice and humans and murine models are commonly utilized to advance radiotherapy in humans [1,2]. We have designed a novel conformal superficial brachytherapy device (CSBT) for preclinical use [3-5]. Tumor regression in mice has been shown following the administration of  $\beta^-$  sources such as yttrium-90 ( $^{90}\text{Y}$ ) [6,7], and there are clinical advantages to using  $^{90}\text{Y}$ . The objective of this study was to evaluate toxicity in a radiation dose escalation study in a non-tumor bearing murine model using the yttrium-90 ( $^{90}\text{Y}$ )-based CSBT.

## AIMS

The aims of the study were:

- 1) Evaluate the utility of Monte Carlo simulated dose distributions in predicting administered radiation dose.
- 2) Determine the temporal development of acute radiation dermatitis following increasing radiation dose.
- 3) Document the extent and degree of clinical skin injury following increasing radiation dose.

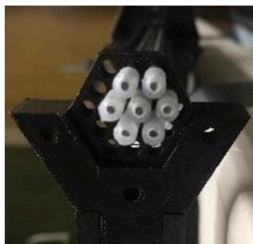
## METHOD

### CSBT Device Source Configuration

- 10 individual cylindrical sources
  - $^{90}\text{Y}$ :  $Q = 2.280 \text{ MeV}$ ,  $\bar{E}_\beta = 0.934 \text{ MeV}$ ,  $R_{\text{CSDA,H}_2\text{O}} = 1.129 \text{ cm}$
  - 0.1 cm thick x 0.1 cm radius
  - Source center-to-center distance = 4.5 cm
- Each source was contained within one of two 3D printed polyacrylic acid tips
  - **Tip-0.5mm**: source-to-surface = 0.5 mm
  - **Tip-surface**: source-to-surface = 0.0 mm
  - Tips were placed in light contact with the target surface

### Dose Escalation Study. (\*approved by the University of Minnesota's IACUC)

- Hairless SKH-1 mice
  - Mice were anesthetized, immobilized and a 2 cm region of skin over the left hindlimb was irradiated
  - Skin toxicity was graded according to a modified veterinary radiation therapy oncology group (VROG) scheme
- Administered Doses: 30 Gy, 40 Gy, 50 Gy, 60 Gy
  - A modification was made mid-study to evaluate the CSBT device with altered tips in the 50Gy and 60Gy groups
  - 30 Gy (Tip-surface)
  - 40 Gy (Tip-surface)
  - 50 Gy (Tip-surface and Tip-0.5mm)
  - 60 Gy (Tip-0.5mm)



Tip-surface

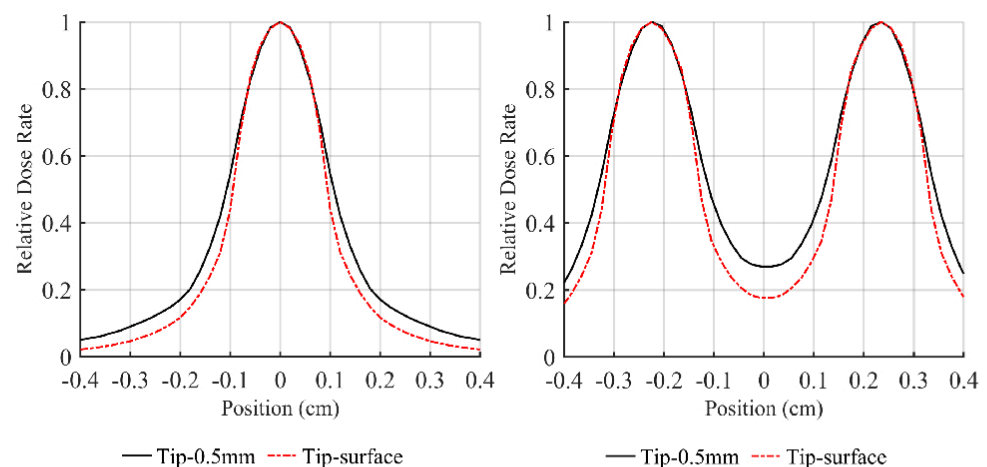


Tip-0.5mm

## MODIFIED VROG SKIN TOXICITY GRADING SCHEME

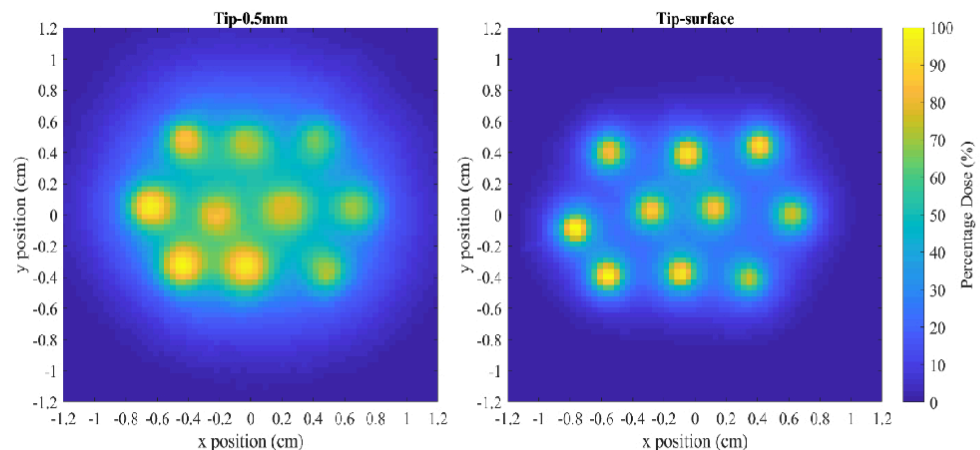
Grade	Description
0	no change over baseline
1	follicular, faint or dull erythema, epilation, dry desquamation
2	tender or bright erythema, patchy moist desquamation, moderate edema
3	confluent moist desquamation (not in skin folds), pitting edema
4	ulceration, hemorrhage, necrosis
5	death

## DOSIMETRY

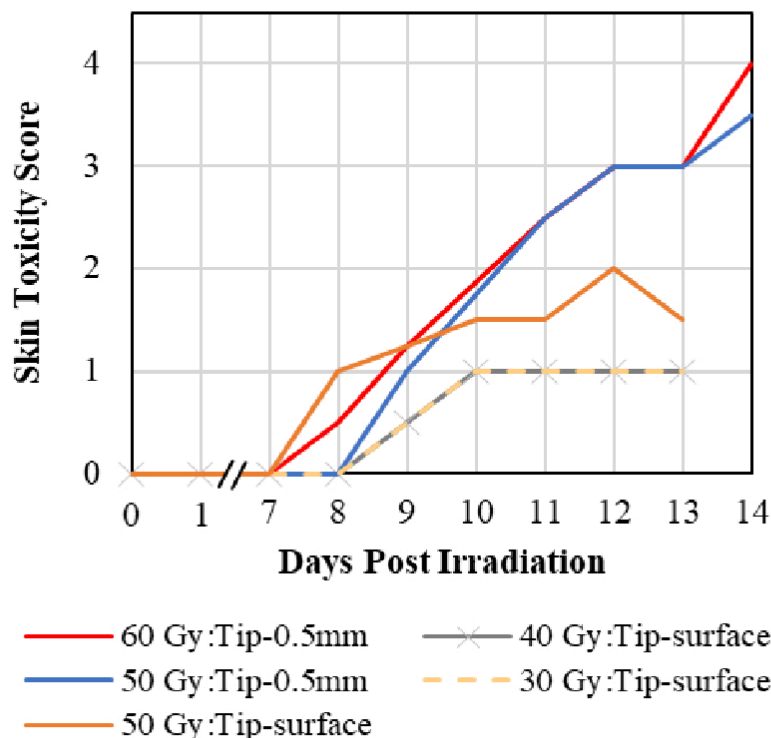
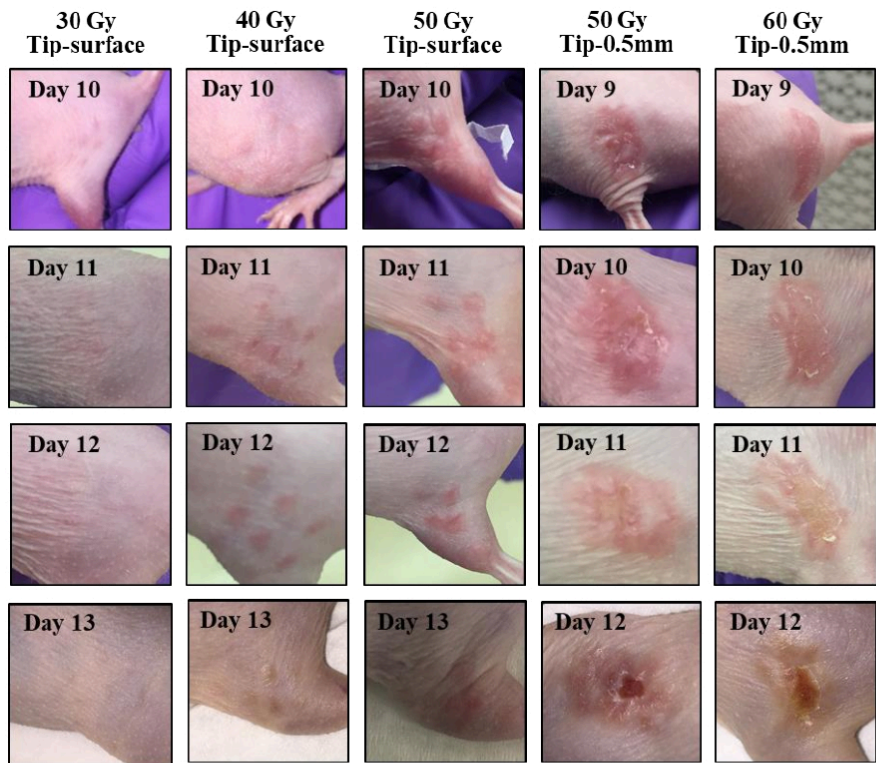


### Surface Dose Rates

- Maximum dose rate:  $D_{\text{max}}(\text{Tip-surface}) = 1.87 \times D_{\text{max}}(\text{Tip-0.5mm})$
- Full-width-half-maximum of single source:  $\text{FWHM}(\text{Tip-surface}) = 0.88 \times \text{FWHM}(\text{Tip-0.5mm})$
- With two sources, local minimum between each source:  $D(\text{Tip-surface}) = 0.65 \times D(\text{Tip-0.5mm})$



## RESULTS



## CONCLUSIONS

- Monte Carlo simulated dose rates predicted administered CSBT dose rates [4]
- Administered radiation dose and severity of skin injury correlated
- Initial appearance of skin damage appeared 7-9 days following exposure and developed earlier in the higher dose groups (50 Gy and 60 Gy) compared to the lower dose groups (30 Gy and 40 Gy).
- Peak toxicity occurred at 12 days following single dose exposure of  $^{90}\text{Y}$ .
- When using the CSBT device with Tip-surface configuration, toxicity was more focal and less severe than skin treated with the Tip-0.5mm configuration.

This data demonstrates that the CSBT device using  $^{90}\text{Y}$  sources requires knowledge of the tip configurations, as decreased homogeneity resulted with a shift in the source of 0.5 mm from the tissue surface. Clinically, a decrease in the severity and extent of radiation dermatitis was observed, despite the prescribed dose being similar in the 50 Gy group. Our future work will focus on defining the extent and degree of histologic injury in these mice. Taken together, this data will permit future dosing strategies to assess the efficacy of the CSBT device for treating tumor-bearing animals.

## ACKNOWLEDGEMENTS

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## CONTACT INFORMATION

Brent Rogers email: Roger929@umn.edu