

# Investigation of Potential Dosimetric Errors in the Treatment Planning System of An Image-Guided Small Animal Irradiator

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## INTRODUCTION

A commercially available small animal radiation research platform, known as SARRP (Xstrahl Ltd, Camberley, UK), is gaining traction for radiobiological studies due to its capability in delivering multi-directional kilo-voltage (kV) x-rays in conjunction with using CBCT image guidance for radiotherapy treatment of rodents. The accuracy of dose calculation from its treatment planning system (TPS) Muriplan, which utilizes the superposition-convolution method, could strongly influence the results of experiments involving animal models of tumor biology and therapy. In this work, three potential dosimetric errors of the system were investigated: (1) beam quality changes arising from the use of a cone and motorized variable collimator (MVC), (2) differences in the backscatter factor due to low-energy photons from the couch top, and (3) resolution limitation for 2D dose distribution calculation.

## MATERIALS AND METHODS

In this study, the comparison of cone and MVC insert as well as a comprehensive investigation into couch backscatter at kV energies for different field sizes were performed using EBT3 film. Identical field sizes of 5 mm x 5 mm and 10 mm x 10 mm were used when comparing the performance of cone and MVC inserts.

### 1. Cone and MVC Insert Comparison

- 5 mm x 5 mm and 10 mm x 10 mm fields of 220 kV photon beams were delivered to EBT3 film dosimeters, which were set up with laser cross-hairs, on a Small Animal Radiation Research Platform (Fig. 1).
- Irradiations were performed at a gantry angle of 0° using 60 mm thick water phantom, comprised of twelve 5-mm thick slices, with EBT3 film placed in between each slice

### 2. Couch Scattering

- 3 mm x 3 mm, 5 mm x 5 mm, 10 mm x 10 mm and 20 mm x 20 mm fields of 220 kV photon beam were used to irradiate EBT3 film placed under a 20 mm thick water phantom with and without couch.
- Identical measurements were performed using Treatment Planning System (Fig. 2) and compared to backscatter measurements

### 3. Resolution limitations

- Measured 2D dose distribution of various field sizes (5 mm x 5 mm and 10 mm x 10 mm) on film, using cone and MVC, were compared with the dose distribution calculated by Muriplan using DoseLab (Mobius Inc).

## RESULTS

### 1. Cone and MVC Insert Comparison

- Depth dose measurements between MVC and cone inserts do not exceed an 11.0% difference, with the maximum discrepancy observed at the surface dose due to greater electron contamination from the MVC as depicted in Fig. 3. Beyond the difference in dose measured at the surface, the differences in percent depth dose between the cone and MVC inserts are within 5.0 % of each other.

### 2. Couch Scattering

- The treatment planning system calculates a 11-12.5% contribution of couch backscatter on dose measurement. Measurements using EBT3 film determined the backscatter contribution to be 12-17% using the same field sizes specified in the treatment planning system (Table 1).

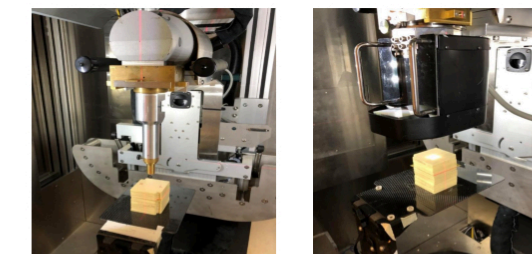
### 3. Resolution limitations

- Using DoseLab to compare the 2D dose distribution measurements from cone and MVC inserts, gamma test comparisons with Mutiplan fail to exceed 80% (going as low as 59.3%) using 2%/1mm criteria (10% threshold).
- The dose distribution from irradiations performed using the cone insert were a better match to the TPS than the MVC for both the 5 x 5 mm<sup>2</sup> and 10 x 10 mm<sup>2</sup> field size. This may be attributed to the larger penumbra observed in the dose distribution from the MVC. There were discrepancies observed between the measured and calculated isodose lines, especially for lower isodose lines (Fig. 4).
- The measured dose distribution is curvier at the field corners than those from Muriplan (TPS), which indicates that the system may not properly take scattering into account. Additionally, due to resolution limitation, errors from dose calculation in penumbra region for field sizes of 5 x 5 mm<sup>2</sup> and 10 x 10 mm<sup>2</sup> were observed to be significant.
- When comparing isodose line from cone and MVC inserts using 2%/1mm criteria for 5 x 5 mm<sup>2</sup> and 10 x 10 mm<sup>2</sup> field size, gamma test show that their comparison fails to exceed 70% (Fig. 5).

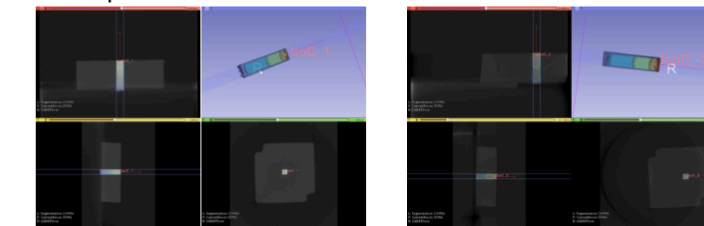
## CONCLUSIONS

- Beam spectrum of MVC is within 5.0 % of the dose delivered using cone beam below surface depth
- Couch scattering from low-energy photons demonstrated some increase at larger field size and pose a considerable contribution to the dose delivered
- Cone insert provides a better match to the TPS isodose lines using 5 mm x 5 mm and 10 mm x 10 mm field size than MVC due to MVC larger penumbra
- This study addresses dosimetric issues of small animal treatment planning in calculating kV small field dosimetry. These inaccuracies are worth discussing to improve radiation research with SARRP in future studies.

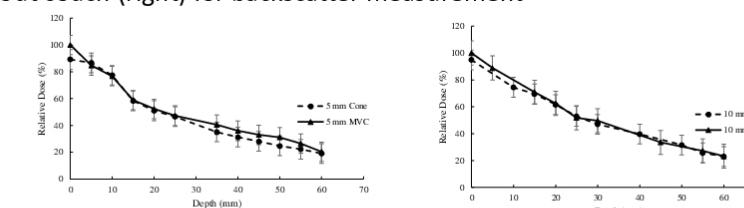
## TABLES AND FIGURES



**Fig. 1:** Use of cone (left) and MVC (right) inserts to irradiate EBT3 films placed between water phantom slices.



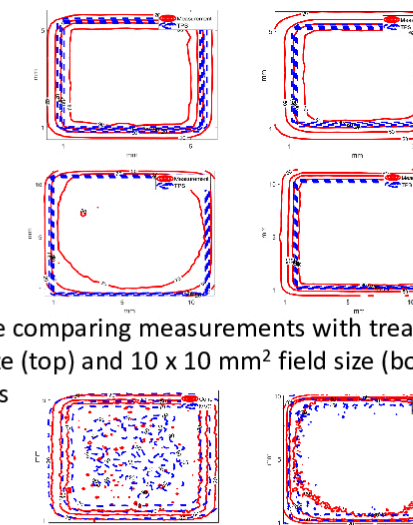
**Fig. 2:** Backscatter calculations performed on Muriplan treatment planning system by calculating dose delivered to bottom of water phantom with couch (left) and without couch (right) for backscatter measurement



**Fig. 3:** Percent Depth Dose measurements comparing cone and MVC inserts using 5 x 5 mm<sup>2</sup> (left) and 10 x 10 mm<sup>2</sup> (right) field size

| Field Size (mm) | Backscatter Factor        |             |
|-----------------|---------------------------|-------------|
|                 | Treatment Planning System | Measurement |
| 3               | 1.125                     | 1.138       |
| 5               | 1.116                     | 1.153       |
| 10              | 1.117                     | 1.177       |
| 20              | 1.112                     | 1.174       |

**Table 1.** Backscatter Factor comparison for measurements and TPS for various field sizes



**Fig. 4:** Isodose line comparing measurements with treatment planning system for 5 x 5 mm<sup>2</sup> field size (top) and 10 x 10 mm<sup>2</sup> field size (bottom) using cone (left) and MVC (right) inserts

**Fig. 5:** Isodose line comparing measurements performed using cone and MVC inserts on film for 5 x 5 mm<sup>2</sup> field size (left) and 10 x 10 mm<sup>2</sup> field size (right)