Preliminary dosimetric validation of a small animal irradiation box for preclinical irradiation research in clinical proton beam facilities

I. Silvestre Patallo[1] , R. Ahmad[2], R. Coos[3], M. Hussein[1], A. Grimwood[4], S. Lucas[3], M. Hawkins[2], C. Baker[4], H. Palmans[1], A. Nisbet[2].

1- Medical Radiation Physics and Science Groups. National Physical Laboratory, UK
2- Department of Medical Physics and Biomedical Engineering, University College London, London, UK
3- University of Namur, Research Unit For Analysis By Nuclear Reactions, NARILIS, BE
4- UCLH Proton Beam Therapy Centre, University College London Hospital, London, UK

INTRODUCTION

- Current unmet need for facilitating pre-clinical research in proton therapy centres[1,2].
- University of Namur designed and built a system to tackle this problem, the IRRAMICE (Figure 1)
- Device is compatible with patient couch lock-bars and has tantalum collimators allowing for targeting of small organs.

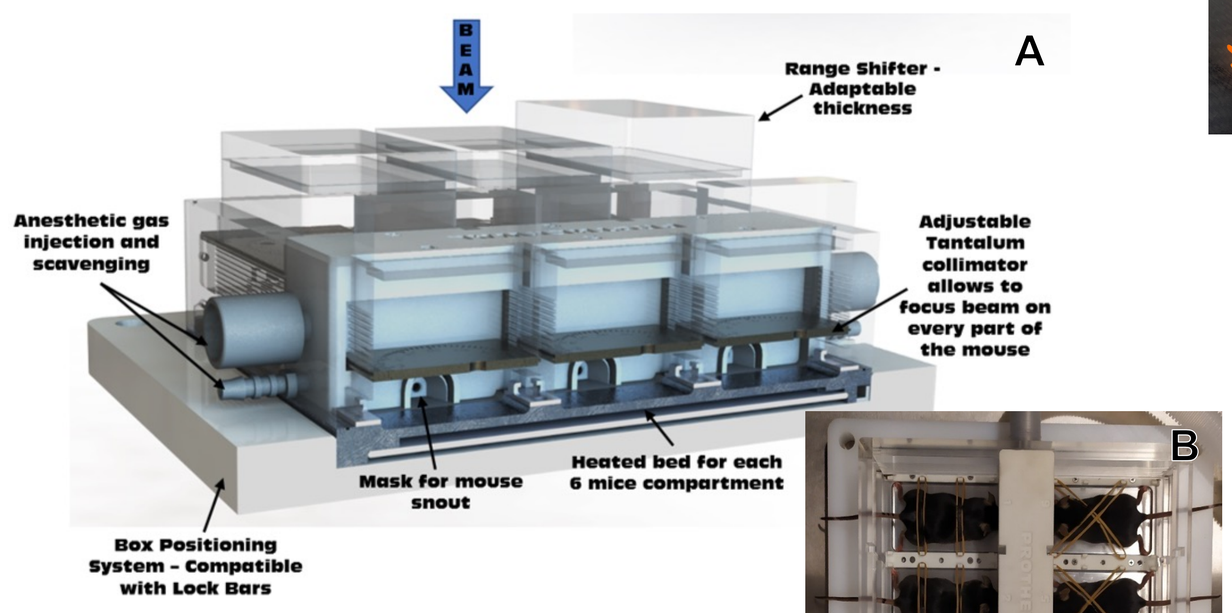


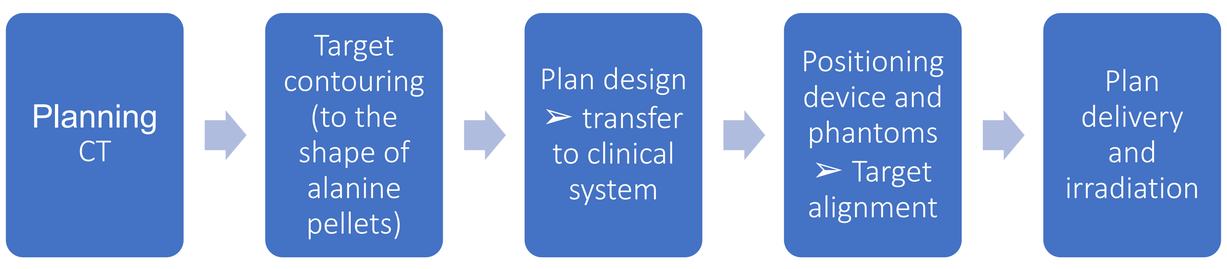
Figure 1: A) IRRAMICE design with different compartments, B) showing the setup in the case where mice are contained in the device

AIM

- Dosimetric characterization of IRRAMICE, evaluation of the effect of Ta collimation.
- To evaluate the applicability of clinical workflows to preclinical experiments with the IRRAMICE.

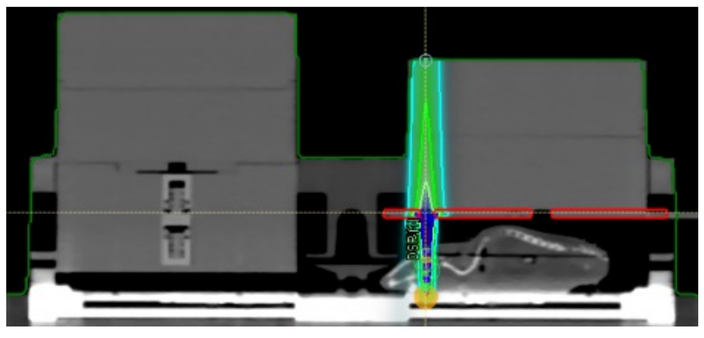
METHODOLOGY

- Measurements were performed at UCLH Proton Beam Therapy Centre.
- Reference measurements with secondary standard Roos ionization chamber (IC) and alanine (UCLH reference conditions).
- Clinical radiation workflow:



- RayStation MC algorithm was used to create single-spot plans with three energy layers, homogeneously targeting alanine pellets in three different configurations: centre of a bespoke WT1 holder (**plan 1**) and in a mouse phantom abdomen (**plan 2**) and brain (**plan 3**). (Figure 2)

Figure 2: Treatment plan for the irradiation of an alanine pellet located in the brain of a mouse phantom



- Additional measurements with the IC EPOM at the depth of the alanine according to **plan 1,** for alanine in the bespoke WT1 holder were performed (Figure 3)

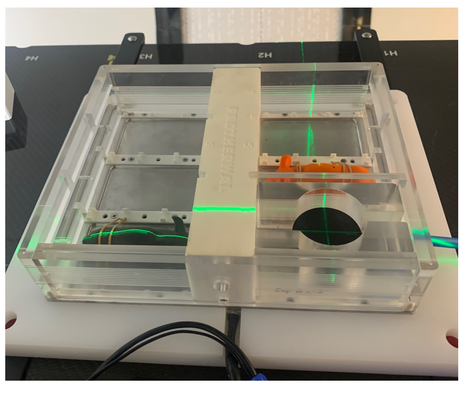


Figure 3: IRRAMICE aligned on treatment couch with lock-bars for reproducible positioning. Roos IC measurements

- The steps of the positioning workflow prior to the irradiations is shown in Figure 4. Pre-treatment imaging was difficult due to the artifacts introduced by the collimator, therefore a final visual confirmation with the Ø 6 mm collimation in place was necessary.

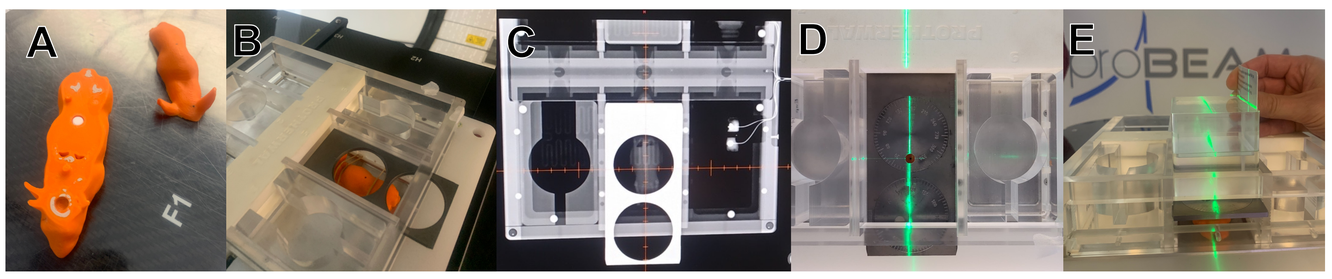


Figure 4: Irradiation workflow – A) alanine pellets placed in mouse phantom, B) phantom and collimator frame placed in the IRRAMICE, C) onboard imaging used to verify target alignment without rotating collimator part to avoid imaging artefacts caused by the tantalum, D) lasers used to confirm aperture alignment and E) final visual assessment prior to irradiation with both PMMA degrader and collimator in place.

RESULTS & DISCUSSION

- Reference absorbed dose to water measurements with Roos IC agreed within 0.7% with alanine measurements (100 MeV single layer proton beam).
- Average difference between TPS calculated dose and dose determined using alanine inside the IRRAMICE (WT1 holder and mouse phantom) was -3.7% (**Table 1**)
- Difference between alanine and TPS calculations needs further investigation. One cause for the difference could be partial irradiation of the pellets.
- Differences could also be explained due to the limitations of MC algorithms for calculations of proton plans for small collimators using a clinical grid size[3]

Table 1: Alanine results measured within the IRRAMICE comparing with those predicted by the RayStation TPS with the average percentage difference quoted relative to the TPS dose.

Alanine position in the irradiation box	TPS, ROI Average Dose (Gy)	Alanine Average Dose (Gy)	% Δ ± SD
Bespoke holder	10.77	10.07	-6.91 ± 0.4
Mouse phantom (Abdomen)	12.18	11.56	-5.4 ± 2.3
Mouse phantom (Brain)	10.27	10.52	1.32 ± 1.0

CONCLUSION

- Preliminary analysis demonstrated that clinical workflows can facilitate accurate conformal dose deliveries to small, collimated targets.
- Additional experiments will be conducted with Gafchromic films to verify the final position of the alanine pellet in relation to the collimator and the assessment of possible partial irradiations.
- Future work aims to engage with stakeholders to determine the size of collimations needed. Subsequently the team will build and characterise new collimators to cover *in vivo* experiments of radiobiological interest.

Note 1: IC readings corrected for recombination and polarity
Note 2: No beam quality correction factors applied to the alanine results.

ACKNOWLEDGMENTS

- Reem Ahmad is by supported by the Radiation Research Unit at the Cancer Research UK City of London Centre Award [C7893/A28990]
- Ileana Silvestre Patallo was supported by the National Measurement System of the UK's Department for Business, Energy, and Industrial Strategy

REFERENCES

[1] Dosanjh M, et al. Radiother. Oncol. 2018;128;14-18. (doi:10.1016/j.radonc.2018.03.008)
[2] Mohan R. Precis. Radiat. Oncol. 2022;6; 164-176. (doi:10.1002/pro6.1149)
[3] Clausen M, et al. Z. für Med. Phys., 2022, (doi.org/10.1016/j.zemedi.2022.10.002)