Minibeams on a Budget: Canine Spatially Fractionated Radiotherapy with the KOALA Dual-Robot System

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INTRODUCTION

1. Minibeam radiotherapy (MBRT) is a new spatially fractionated radiotherapy approach with normal tissue sparing benefits.
2. Global disparities in access to radiotherapy remain a major barrier to effective cancer treatment.

We combine MBRT delivery with a unique, low-cost, non-coplanar robotic kV x-ray system [1] to simulate treatment of a **canine glioblastoma patient.**

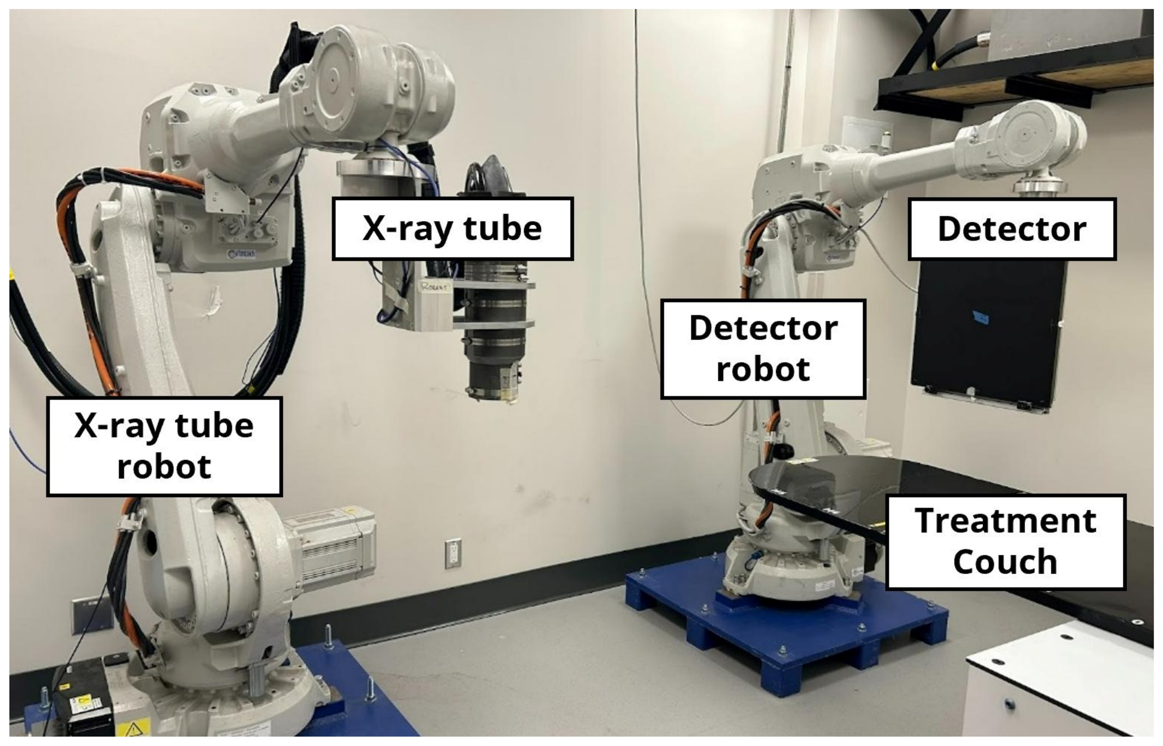

Fig. 1: KOALA system, consisting of a 225 kVp x-ray tube and a flat panel detector, mounted on distinct robotic arms (Linden Technologies, USA).

METHODS AND MATERIALS

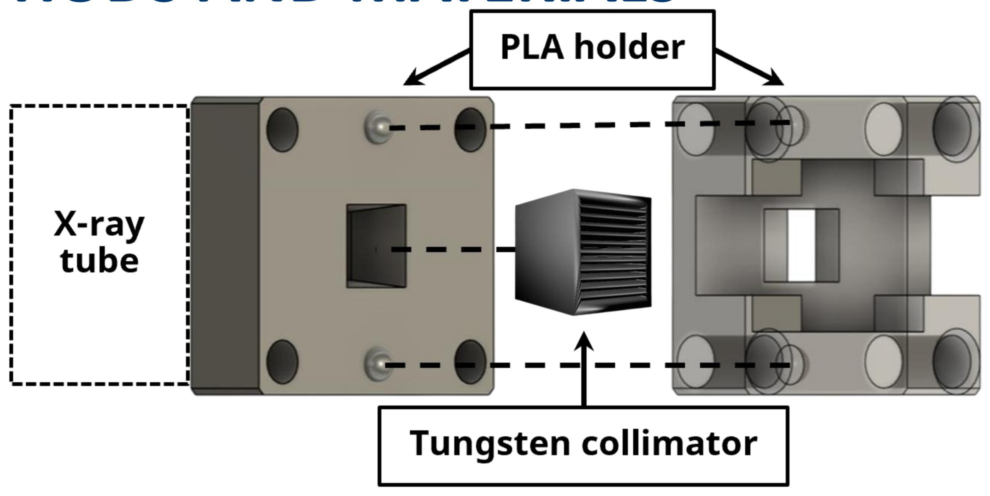

Fig. 2: 3D printed collimator (Dunlee, Germany) and holder. The 1 cm³ divergent collimator has 300 µm slits at 870 µm center-to-center distances at the exit face.

A Monte Carlo (MC) model of KOALA MBRT was built in TOPAS and validated with Gafchromic EBT4 measurements in-air and in solid water.

Two **non-coplanar 225 kVp MBRT treatment plans** (2 mm Al and 0.5 mm Cu beam filtration) were created and compared to a clinical 6 MV VMAT plan. The full set and subsets of minibeams from the treatment plan was delivered to a canine head phantom [2] to assess plan delivery feasibility.

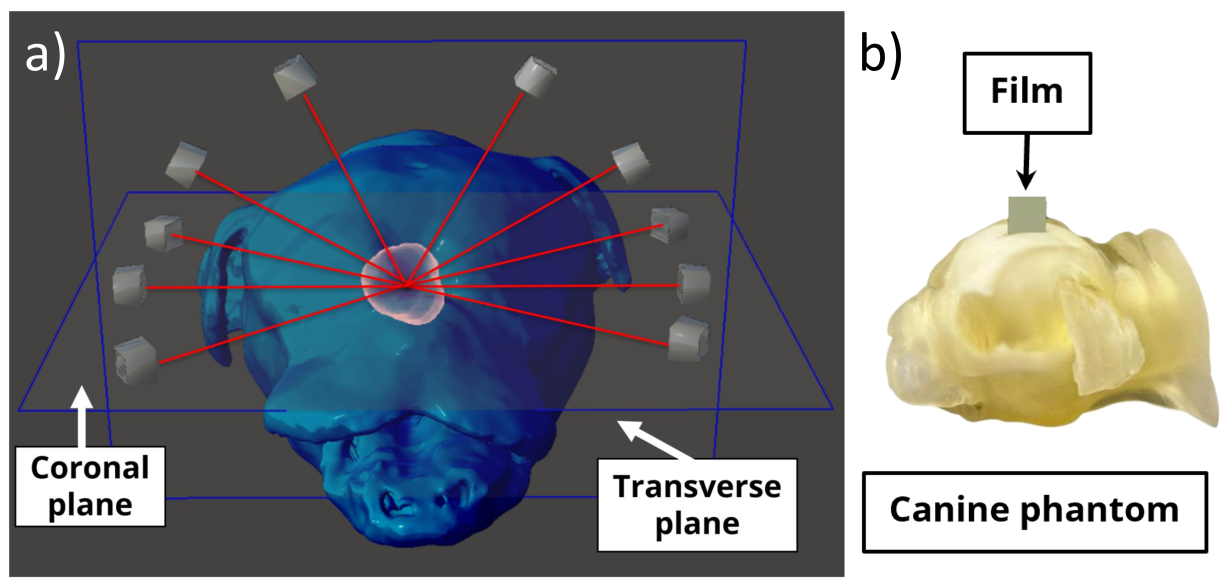

Fig. 3: a) Ten minibeam step-and-shot treatment plan. b) Canine phantom.

RESULTS

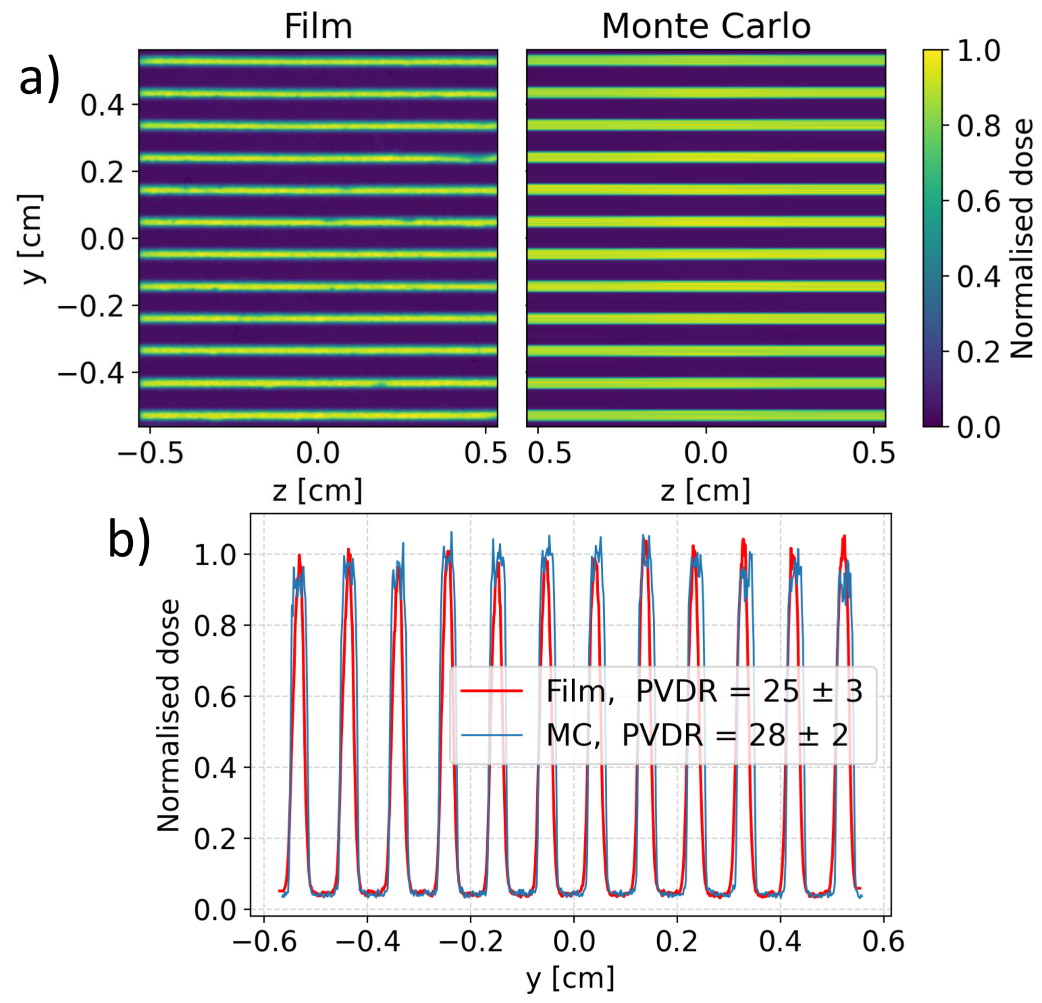

*Fig. 4: **In-air dosimetry.** a) Film and MC dose maps. b) Profiles.*

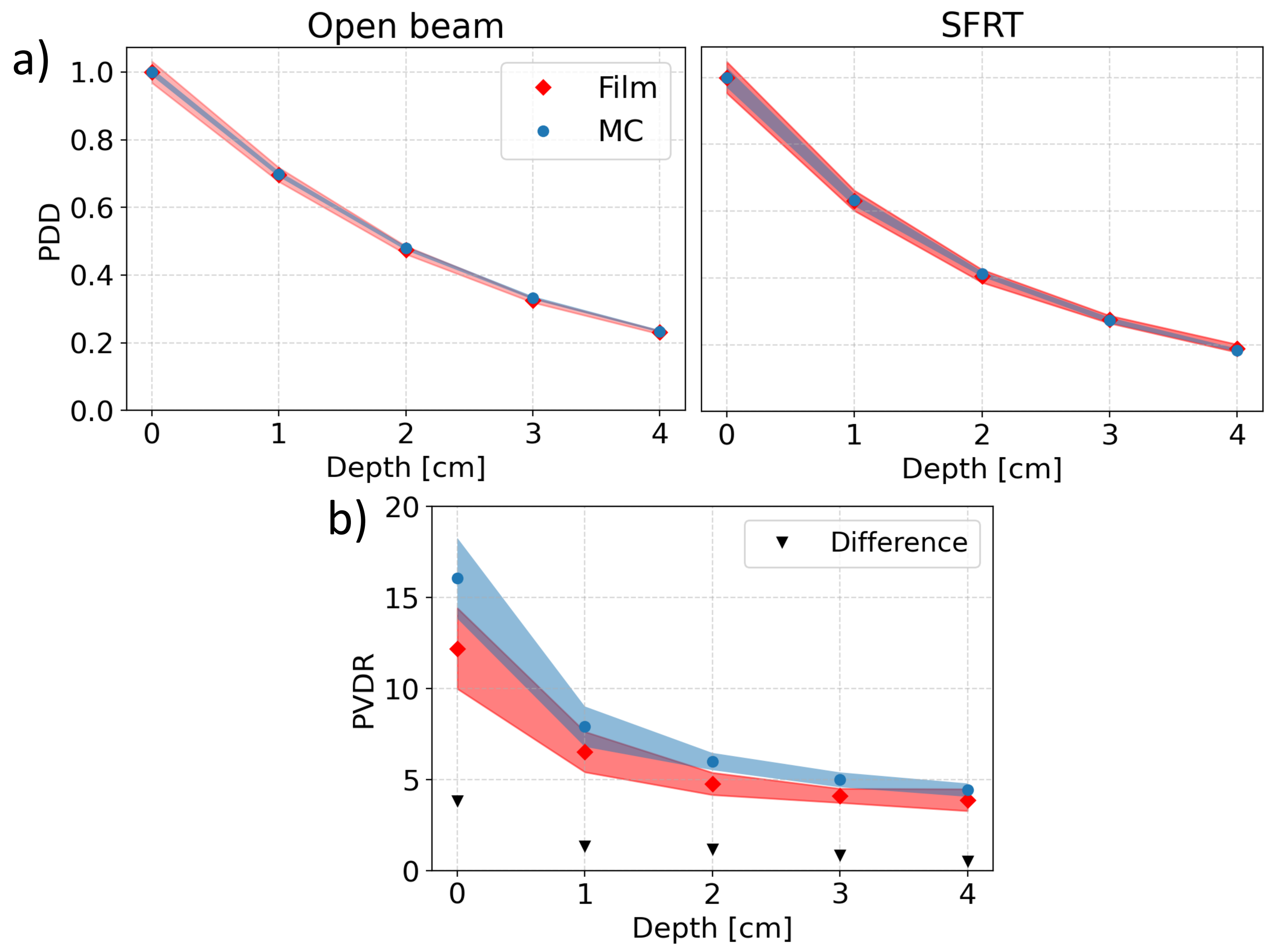

*Fig. 5: **Solid water phantom dosimetry.** a) Open beam and collimated Percent Depth Doses (PDDs). b) Peak-to-valley dose ratios at depths (PVDRs).*

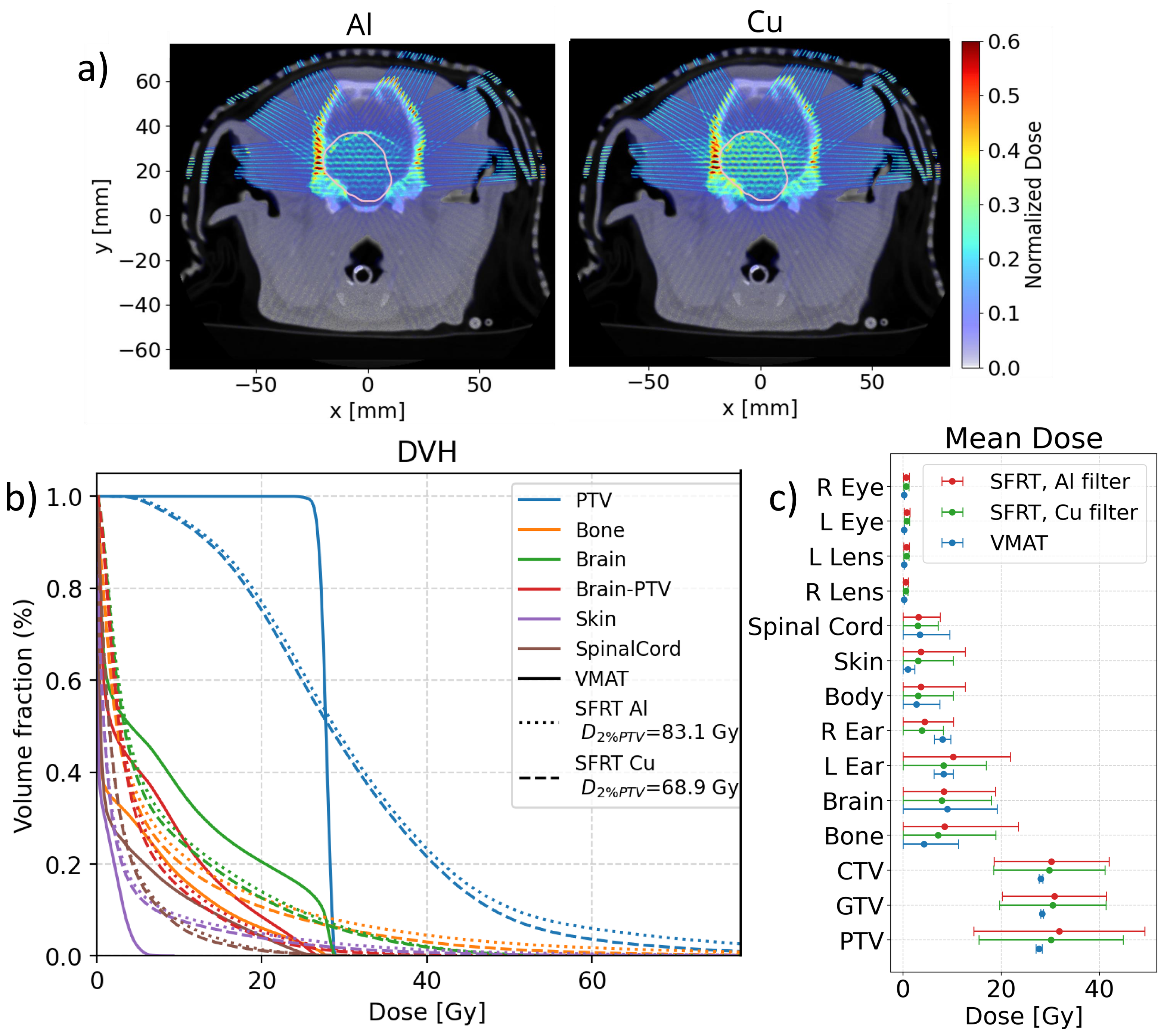

*Fig. 6: **Canine patient treatment plans.** a) Simulated Al- and Cu-filtered dose distributions. b) Corresponding DVHs and c) mean doses.*

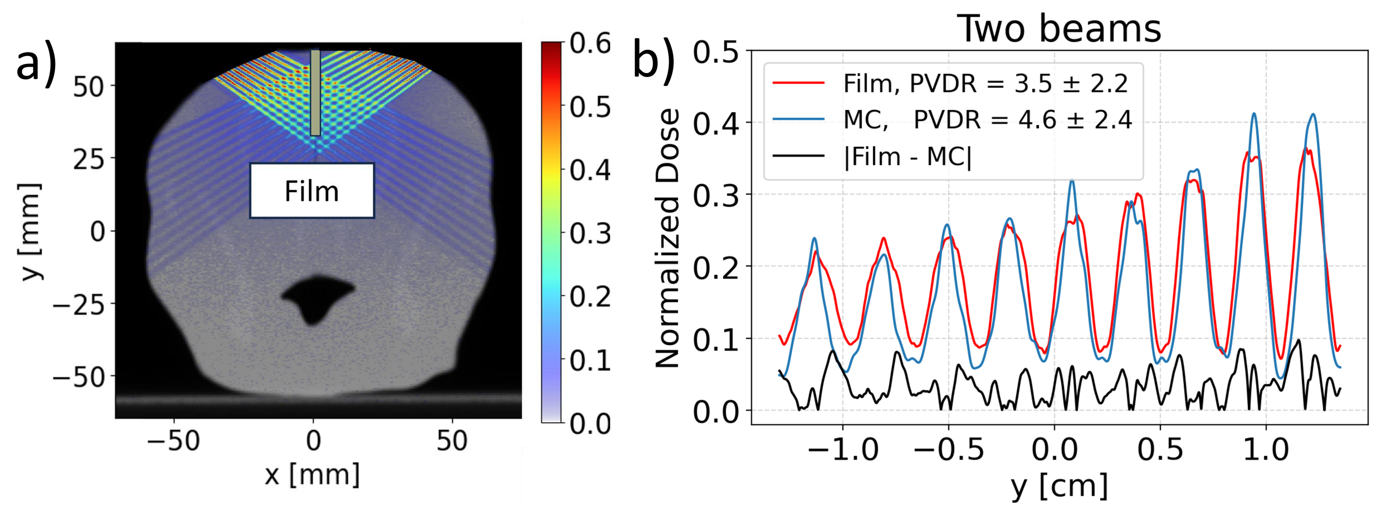

*Fig. 7: **Canine phantom dosimetry.** a) Simulated two-minibeam Al-filtered dose distribution. b) Profiles.*

DISSCUSION

Experimental validation of MBRT delivery yielded a sufficient agreement with simulations in-air and in a solid water phantom (fig. 4 and 5, PVDRs ≤ 2σ and PDDs within ≤ 0.4%).

The MBRT treatment plan target dose was non-uniform and spatial fractionation was preserved in healthy tissue for tissue-sparing benefits (fig. 6). PVDR at the skin surface past the ear (x = -5.0 cm on fig. 6a.) was 9.8 ± 3.2 for the Al-filtered beam (8.5 ± 2.1 for Cu) entering trough the left canine temple. Mean MBRT doses to organs at risk were within 15% of VMAT, except for skin (+57% for Al- and +51% for Cu-filtered beams), bone (+33% for Al and +25% for Cu) and the left ear (-29%for Al and -35% for Cu).

Treatment time was found to be 54 minutes for Al- and 111 minutes for Cu-filtered beams.

Mean two-minibeam map difference of 3.5 ± 2.2% (fig. 7) suggest a negligible impact of the isocenter position uncertainty for coplanar beams.

CONCLUSIONS

This work presented the potential of a unique low-cost robotic x-ray tube system to offer tissue-sparing canine MBRT. Following manufacturer calibration, the robotic motion accuracy would be sufficient for non-coplanar MBRT delivery.

Blurring of the MBRT dose distribution due to patient motion during the treatment could be lessened by placing the MBRT collimator directly on the patient, as opposed to mounting the collimator on the x-ray tube [3].

REFERENCES

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[3] Grams et al. (2024). Int J Radiat Oncol Biol Phys 120(5):1423-1434.

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