Feasibility of Biology-Guided Radiotherapy of Small Tumors with Extended Field-of-View PET Detectors

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BACKGROUND

- **Biology-guided radiotherapy (BgRT)** uses emissions from tumor targeting position emission tomography (PET) radiotracers to guide radiotherapy treatment autonomously in real-time.
- The RefleXion **X1** system requires activity concentration **(AC) > 5 kBq/mL**; small, low-uptake lesions fall below this threshold due to partial volume limitations and are therefore ineligible.
- The next-generation **X2** adds an **extended axial field-of-view (FOV)** to achieve higher sensitivity.

PURPOSE

Can the X2, with an extended-FOV, **lower the AC threshold** and expand BgRT patient eligibility to small tumors?

METHODS

- **Custom 3D-printed phantom** with six spheres (8, 9, 11, 13, 16, 20 mm) in an ArcCHECK-compatible cylindrical insert.
- Focused on the challenging **9 mm & 11 mm** low-uptake targets
- **^{18}F-FDG** filled to TBR of 5:1, 10:1, 15:1, 20:1; AC measured on the X2 (5 kBq/mL safeguard disabled).
- 10 Gy/fx BgRT plans were generated; delivery verified on **ArcCHECK with 3%/2 mm gamma**.
- Planning target volumes (PTV) and biology tracking zones (BTZ) were generated using symmetric 5 mm relative expansions.

Target Diameter	PTV Diameter	BTZ Diameter
9 mm	19 mm	29 mm
11 mm	21 mm	31 mm

Table 1. *The gross tumor volume, planning target volume, and biology tracking zone are reported for the two spheres investigated in this work.*

RESULTS

- **7 of 8 BgRT plans were deliverable**, several with activity concentration far below the 5 kBq/mL limit; 9 mm lesions previously untreatable on the X1 were treated.
- **11 mm targets:** excellent delivery at all TBRs, with γ 97.3% (20:1), 96.9% (15:1), 98.8% (10:1), 98.2% (5:1); AC as low as 1.2 kBq/mL.
- **9 mm targets** (untreatable on X1): excellent delivery at TBR ≥ 10:1, with γ 99.2% (20:1), 96.3% (15:1), 99.2% (10:1); AC to 1.48 kBq/mL.
- **Safeguards correctly blocked** the 9 mm / 5:1 case due to insufficient signal.

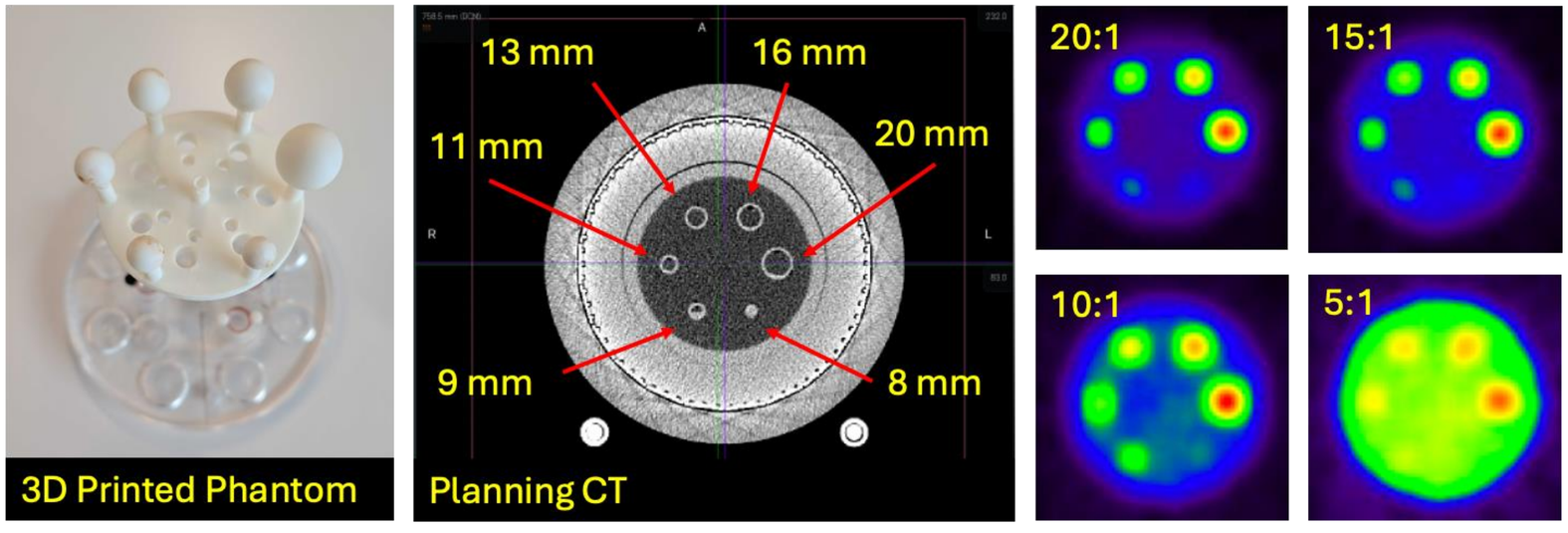

Figure 1. *Custom 3D-printed small-target phantom (left); planning CT with six spheres, 8–20 mm (center); planning PET at 20:1, 15:1, 10:1, 5:1 target-to-background ratios (right).*

KEY RESULTS

Target	TBR	AC (kBq/mL)	γ 3%/2 mm
9 mm	20:1	4.3	99.2%
9 mm	15:1	2.8	96.3%
9 mm	10:1	1.5	99.2%
11 mm	20:1	6.9	97.3%
11 mm	15:1	4.3	96.9%
11 mm	10:1	3.1	98.8%
11 mm	5:1	1.2	98.2%

Table 2. *Table of 9 mm and 11 mm diameter spheres with the filled TBR, activity concentration, and 3%/2mm gamma values.*

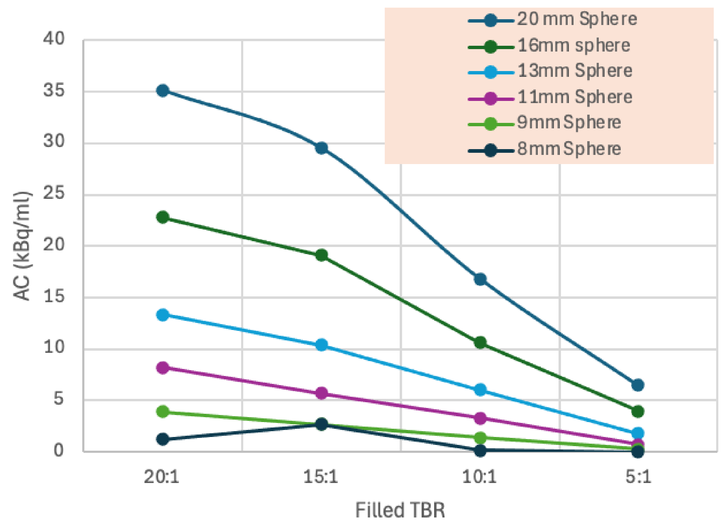

Figure 2. *Measured activity concentration vs. filled TBR across sphere sizes; the 5 kBq/mL threshold was disabled.*

CONCLUSIONS

- Extended-FOV PET on the RefleXion X2 enabled **accurate BgRT delivery to small (9–11 mm), low-uptake targets**, including cases well below the 5 kBq/mL AC threshold.
- **9 mm lesions previously ineligible on X1** were successfully planned and delivered (γ ≥ 96.3%), while safeguards still blocked genuinely insufficient-signal cases.
- Extended FOV has the potential to **expand BgRT eligibility for small tumors.**

CLINICAL IMPACT

If validated, a lower AC threshold could extend BgRT to patients with **small or low-avidity tumors** that are currently ineligible on the X1 platform.

FUTURE WORK

- Motion-phantom studies are needed to establish a **safe AC threshold for moving targets** before clinical translation.
- **Film measurements** should be performed supplementally to ensure that target coverage is maintained and assess the influence of PET to contour alignment in accurately delivering dose.

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Disclosure: *Investigational RefleXion X2; 5 kBq/mL AC safeguard disabled for research use only.* ***Anchor Point Tracking is pending 510(k) clearance and is not commercially available.***