Advancing Dosimetry for Radiopharmaceutical Therapy with a Novel Ionizing Quantum Imaging Detector

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Radiopharmaceutical therapy (RPT) shows promise for improving survival for patients with metastatic prostate cancer. However, the characterization of RPT radiation dose, known as dosimetry, is underdeveloped and poorly understood. Further RPT advancement will require novel tools that can precisely measure RPT dosimetry. This project aimed to benchmark a novel system for measuring RPT dosimetry: the Ionizing Quantum Imaging Detector (iQID).

The scintillator-based iQID maps individual alpha or beta emissions on a 10×10 cm2 detector. We tested spatial resolution by measuring the full width at half maximum (FWHM) of a collimated (5 μm × 5 mm) alpha-emitting source (5 mCi, ^{210}Po). We repeated the spatial resolution test for two scintillator materials (ZnS:Ag and Gaddox) and at 17 positions on the detector surface. To ensure source placement reproducibility, a custom holder was designed and printed on a Bambu Lab X1-Carbon printer. We tested variations in FWHM with position via Bonferroni-corrected Spearman's Correlation (α=0.02). The number of alpha particles detected from a 50.2±1.1 Bq source (^{243}Am, ^{242}Pu, and ^{239P}u) over 48 hours quantified sensitivity. Finally, we quantified uniformity via the variation in total particles detected from 200 Bq of ^{210}Po at 17 positions on the detector surface.

The FWHM averaged 57.35 ± 4.36 μm with ZnS:Ag and 57.29 ± 4.78 μm with Gaddox. FWHM was insensitive to position on the detector ($p \geqslant 0.03$). The sensitivity measurement yielded 4,241,627 counts, representing 48.69 ± 0.02 Bq and 97% sensitivity. Uniformity tests revealed a significant variation in counts detected with radial distance from the detector center with a loss of 450 counts/mm from the center.

Our results revealed the novel iQID can identify individual alpha emissions with high sensitivity at spatial resolutions approaching the cellular scale. However, corrections for non-uniform response may be needed. With advanced RPT dosimetry, precision RPT can offer optimal cancer management to patients with metastatic prostate cancer.

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