2026 JULY 19–22 VANCOUVER, BC
JOINT AAPM | COMP MEETING

Quantitative Assessment of CT Artifact Severity for Cs-131 Brachytherapy Seed Designs With and Without a Radiographic Marker

Grace MacDonald, ScM[1], Alana Corinne Pankopf, ScM[1], Edward Walsh, PhD[1], Ulrich Langner, PhD[2], Mark Rivard, PhD[1]
[1]Brown University, Providence, RI, [2]Brown University Health, Providence, RI

Objectives

- Establish quantitative evidence that removing the internal high-Z (gold) marker from Cs-131 brachytherapy seeds reduces CT imaging artifacts, without compromising clinical usability
- Isolate the gold marker's specific contribution to artifact formation using two seed designs that are geometrically identical apart from the marker
- Quantify artifact severity using the ρ-index derived from extreme-value statistics of local HU gradients
- Test whether artifact reduction holds across multiple phantom environments (bolus-only and bovine tissue)
- Evaluate whether no-marker seed design produces consistent and significantly lower CT artifacts than gold-marker seeds

CONTACT

Grace MacDonald
Brown University Health
mmacdonald@brownhealth.org
401-368-7343

INTRODUCTION

GammaTile therapy delivers surgically targeted brachytherapy using Cs-131 seeds embedded in bioresorbable collagen tiles, implanted along the walls of the resection cavity immediately following intracranial tumor removal. CT is the modality commonly used for the post-implant dose assessment due to its spatial resolution, speed, and ability to provide Hounsfield Unit (HU) information for dose reconstruction. Conventional brachytherapy seeds include an internal high-Z gold marker specifically to improve radiographic visibility and confirm seed position. However, the high density and atomic value of the gold marker results in CT artifact production. Beam hardening, photon starvation, and scatter around the marker introduce inconsistencies in the projection data that cause streaking and dark void regions surrounding the seeds in the reconstructed images. Because the highest radiation dose is delivered immediately adjacent to each seed, these artifacts obscure the tissue that most needs to be evaluated, complicating seed localization, tissue characterization, and dose reconstruction accuracy.
To address the problem at its source, this work evaluates a new design of the seeds with the removal of the gold marker entirely. This design directly isolates the marker's contribution to CT artifact severity and tests whether it's removal can meaningfully improve CT imaging compatibility.

METHODS AND MATERIALS

Two non-radioactive versions of the IsoRay CS-1 Rev2 Cs-131 seed were compared: a standard **gold-marker** design (0.25-mm gold wire in a ceramic-coated glass tube, titanium-encapsulated) and a geometrically identical **no-marker** version with the gold wire omitted. Seeds were imaged across three phantom datasets, two bolus-based and one embedded in bovine tissue, using a fixed CT protocol (Siemens SOMATOM Confidence, 120 kVp, 1.5-mm slices). ROIs adjacent to each seed and matched background regions were segmented in 3D Slicer. Artifact severity was quantified with the **ρ-index**: per-ROI HU gradient maxima were fit to a Gumbel distribution, and
$\rho = \sqrt{(\lambda_{ROI}^2 - \lambda_{bg}^2)}$ was computed to normalize artifact signal to local background noise. Pooled ρ-index values were compared between seed types with a one-sided Mann–Whitney U test.

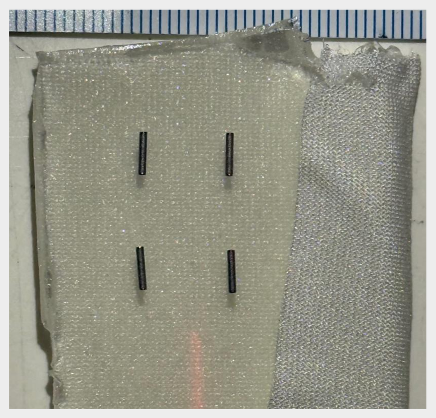

Figure 1. Seed configuration used in CT dataset 1 in bolus

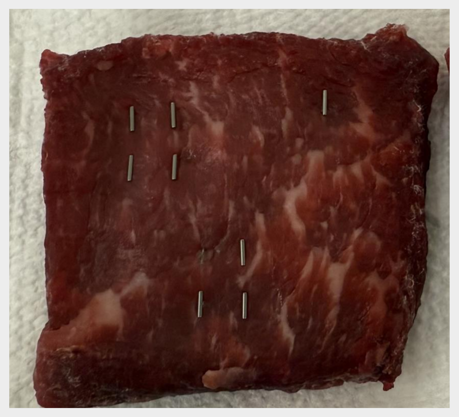

Figure 2. Seed configuration used in CT dataset 3 in bovine tissue

RESULTS

- Qualitatively, gold-marker seeds produced visibly larger dark void regions than no-marker seeds across all three imaging sessions
- Pooled across all 12 ROI pairs from three datasets, the ρ-index was **15.4 ± 4.1** for gold-marker seeds vs. **6.8 ± 3.6** for no-marker seeds
- This difference was highly statistically significant: one-sided Mann Whitney U-test, **$U = 135.0$, $p = 1.54 \times 10^{-4}$**
- Effect was consistent across all three datasets, including both bolus-only and bovine-tissue environments
- Distributions for gold-marker and no-marker seeds pooled across all sessions showed limited overlap, reinforcing the robustness of the effect

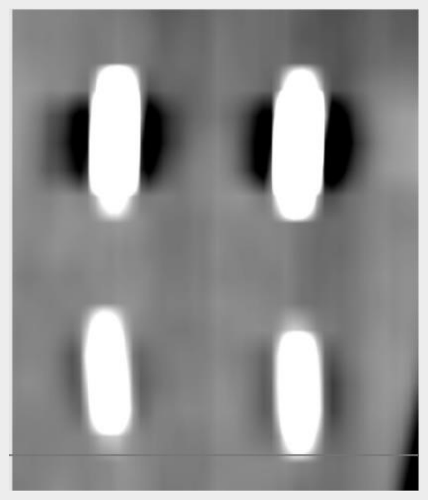

Figure 3. CT image from dataset 1 with gold-marker seeds on top row and no-marker seeds on bottom row

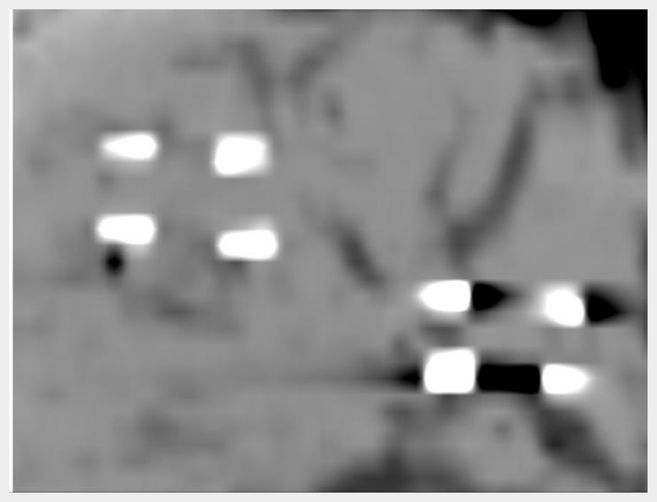

Figure 4. CT image from dataset 3 with gold-marker seeds on the right and no-marker seeds on the left

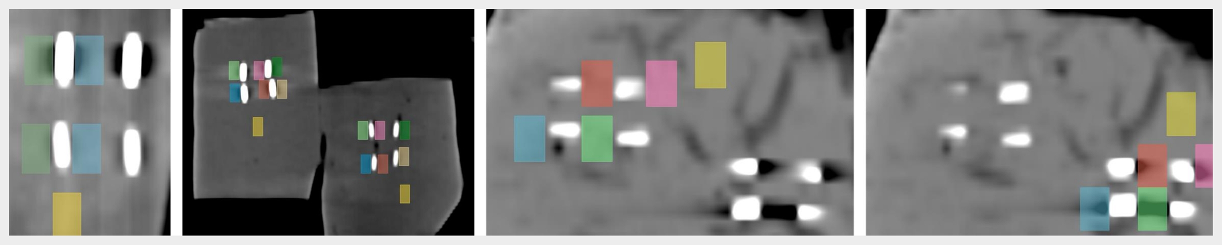

Figure 5. ROI placements across all three datasets. From left to right: 1, 2, 3 no-marker, 3 gold-marker

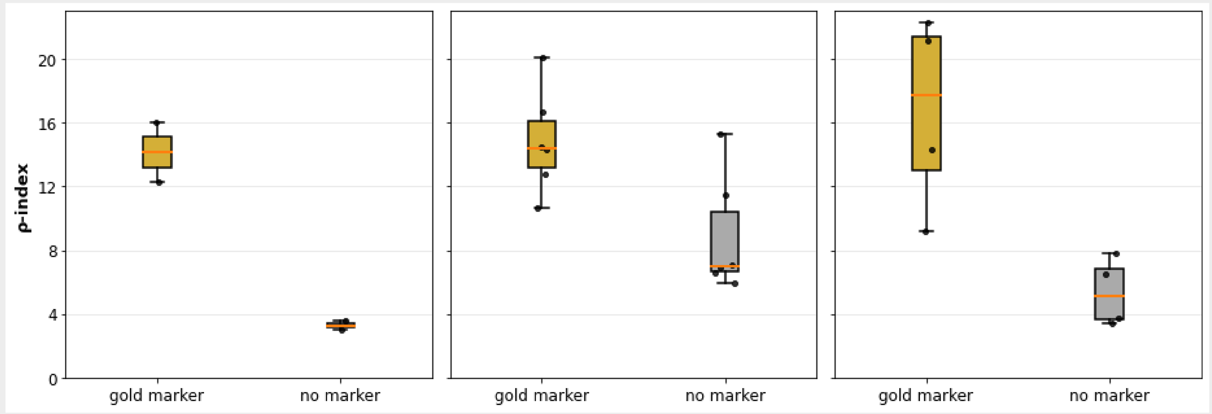

Figure 6. Boxplots of artifact severity quantified by the ρ-index for gold-marker and no-marker seed designs

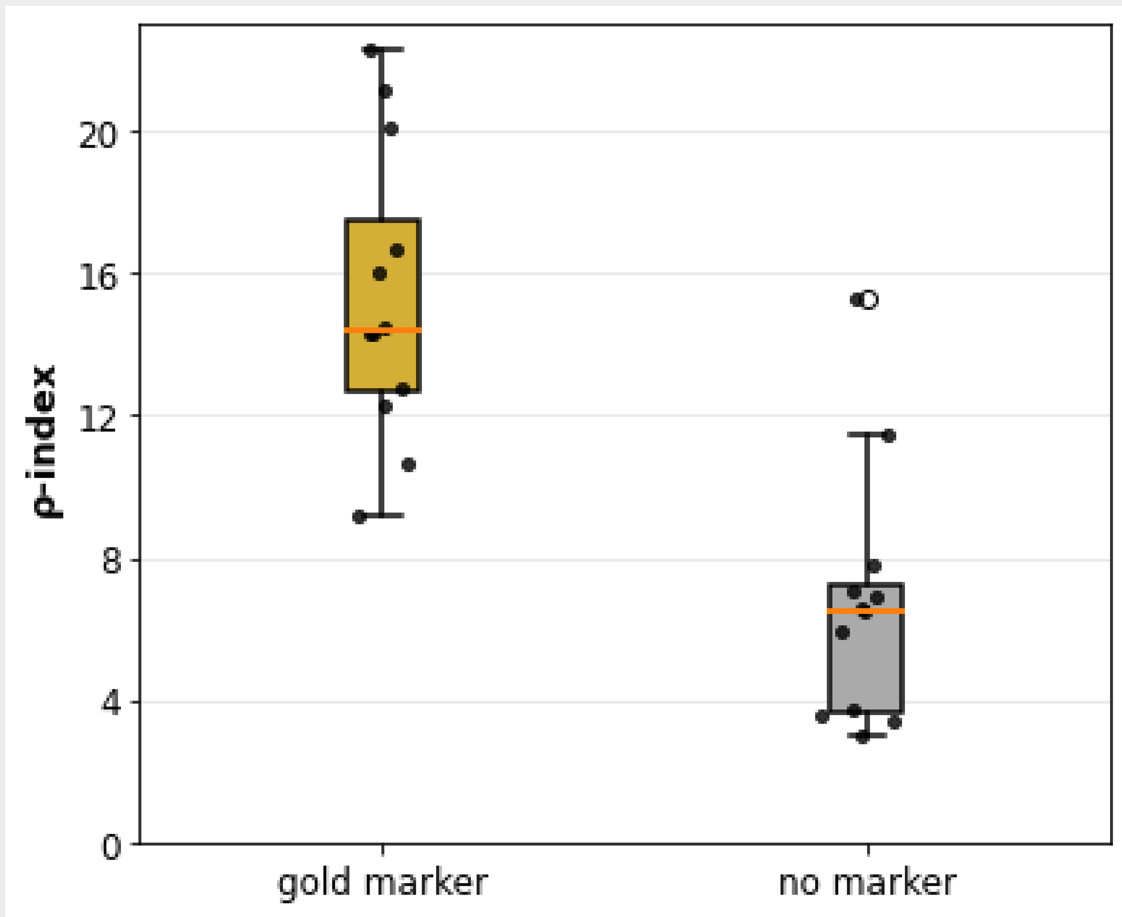

Figure 7. Boxplot of artifact severity (ρ-index) for gold-marker and no-marker seed designs with data pooled across all imaging sessions

DISCUSSION

- The higher ρ-index for gold-marker seeds is consistent with the known physics of metal artifacts: gold's high atomic number (Z=79) and density (19 g/cm³) drive stronger beam hardening and photon starvation than the surrounding titanium shell alone produces
- Because the two seed versions are geometrically identical apart from the gold marker, this design directly isolates the gold marker as the dominant contributor to CT artifact severity
- Clinically, reduced artifact severity should improve visualization of tissue immediately adjacent to the seed, where the highest brachytherapy dose is delivered, supporting more reliable post-implant dose assessment and seed localization
- The consistency of the effect across bolus and bovine-tissue environments suggests the benefit should translate to the heterogeneous soft-tissue conditions of a GammaTile implant
- Limitations: phantom-based data, modest sample size (12 ROI pairs), further work should include full dose-reconstruction comparisons between seed designs and validation in more anatomically realistic models

CONCLUSIONS

- Removing the internal gold marker from the Cs-131 GammaTile seed design significantly reduces CT artifact severity ($\rho = 15.4 \pm 4.1 \rightarrow \rho = 6.8 \pm 3.6$, $p = 1.54 \times 10^{-4}$), consistently across three independent phantom environments
- This is, to our knowledge, the first demonstration that redesigning Cs-131 seed material composition,can meaningfully improve CT imaging compatibility
- A no-marker seed design may improve seed localization, visualization of surrounding tissue, and confidence in post-implant dosimetric assessment, advancing brachytherapy source design toward better imaging performance and treatment accuracy
- Future work: full dose-reconstruction comparisons, validation in tissue-realistic models, and larger sample sizes.

REFERENCES

1.Cammin J. A robust index for metal artifact quantification in Computed Tomography. *J Appl Clin Med Phys.* 2024;25(8).
2. Rivard MJ. Brachytherapy dosimetry parameters calculated for a ¹³¹Cs source. *Med Phys.* 2007;34(2):754–762.
3. Wernicke AG, et al. Clinical outcomes of large brain metastases treated with neurosurgical resection and intraoperative ¹³¹Cs brachytherapy. *Int J Radiat Oncol Biol Phys.* 2017;98(5):1059–1068.
4. Hsieh J. *Computed Tomography: Principles, Design, Artifacts, and Recent Advances.* SPIE Press; 2009.
5. Gjesteby L, et al. Metal artifact reduction in CT: where are we after four decades? *IEEE Access.* 2016;4:5826–5849.