MEDICAL PHYSICS COMMUNITY INSPIRATION INNOVATION IMPACT
2026 JULY 19–22 VANCOUVER, BC
JOINT AAPM | COMP MEETING

Proof-of-Concept for Intraoperative Dosimetry Assessment of GammaTile Placement Using Intraoperative MRI and 3D Slicer Software

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ABSTRACT

Purpose: GammaTile cesium-131 collagen tiles provide immediate postoperative radiation therapy for brain tumors by lining the resection cavity, delivering a steep dose fall-off to target residual disease while sparing healthy tissue. However, intraoperative verification of tile placement and dose coverage remains challenging due to limited real-time tools. We developed and tested a proof-of-concept method for real-time dosimetry assessment during GammaTile placement in the operating room (OR) using a retrospective intraoperative MRI (iMRI) integrated with open-source 3D Slicer software.

Methods: Under IRB-approved retrospective study STUDY00010486, post-resection iMRI scans (T1-weighted sequences optimal for cavity visualization) from a clinical case was analyzed. Images were imported into 3D Slicer for simulated tile positions. A prototype approach modeled fixed 4-seed Cs-131 geometry per tile, applied TG-43-based dose calculations, and generated 3D dose distributions and isodose lines. Drag-and-drop, tile rotation/translations, and dragging features were implemented for real-time adjustment in both 2D and 3D visualizations. Processing time and feasibility for potential intraoperative adaptation were assessed.

Results: Retrospective application to initial clinical case demonstrated efficient iMRI import, ability to drop tiles in the cavity, and dose computation within 5-10 minutes. Underdosed or overlapped regions could be visualized, highlighting potential intra-operative opportunities for refinement. Compared to conventional post-procedure verification, this workflow could provide enhanced dosimetric insight into intraoperative decisions, with qualitative improvements in coverage assessment.

Conclusions: This retrospective proof-of-concept confirms the feasibility of using iMRI and 3D Slicer for GammaTile dosimetry evaluation, offering a low-cost, open-source framework for real-time intra-operative dosimetry. Translation to prospective real-time intraoperative use could improve placement accuracy and patient outcomes; additional prospective validation and advanced TG-43 integration are needed for clinical implementation.

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INTRODUCTION

GammaTile is an FDA-cleared (2018) surgically targeted radiation therapy in which bioresorbable collagen tiles embedded with cesium-131 (Cs-131) seeds are placed along the resection cavity at the time of surgery, delivering immediate postoperative dose with steep fall-off that treats residual disease while sparing surrounding brain.

Despite growing clinical adoption, the current workflow has no real-time verification of tile placement or dose coverage in the operating room. Placement is guided largely by surgeon judgment, and dosimetric confirmation happens only after the procedure, after brain shift and cavity deformation have already changed the geometry the plan assumed. In a 21-implant recurrent-glioblastoma series, the median high-risk CTV (HR-CTV) D90 was 56.0 Gy against a 60 Gy prescription (from 31.7 to 98.7 Gy) showing frequent underdosing with wide case-to-case variability (Zhang et al., 2024).

Intraoperative visualization is already standard in other types of brachytherapy (e.g. prostate; Polo et al., 2010) but has not yet been translated to GammaTile. We present a proof-of-concept treatment-planning module that adapts this concept to GammaTile using retrospective iMRI and open-source 3D Slicer, with the goal of enabling dosimetric insight during surgery rather than after.

METHODS AND MATERIALS

Under IRB-approved retrospective study STUDY00010486, post-resection T1-weighted iMRI scan was analyzed. All processing was performed in open-source 3D Slicer (Fedorov et al., 2012) using a custom scripted module developed for this work.

Workflow:

- Import — iMRI volume loaded into 3D Slicer and registered to the resection cavity.
- Seed & Tile modeling — each tile modeled as a fixed 20 × 20 mm geometry carrying 4 Cs-131 seeds & individual seed capability.
- Dose calculation — full TG-43U1 2D line-source formalism (Rivard et al., 2004), with constants and function values from the CLRP v2 (Safigholi et al., 2020) consensus dataset for CS-1 Rev2.
- Visualization — 3D dose distributions and 2D/3D isodose lines generated and overlaid on the iMRI.
- Real-time adjustment — drag-and-drop placement with per-tile rotation and translation, enabling interactive repositioning in both 2D slices and the 3D render.
- Export — per-seed and per-tile coordinates (local and RAS, mm), and the dose grid to DICOM RTDOSE (Gy) or NRRD for downstream QA.

Processing time and feasibility for potential intraoperative adaptation were assessed.

Figure 1 shows the 3D Slicer-based UI for the surgeon in the operating room.

RESULTS

Full dose computation completed in 5–10 minutes, including iMRI import, HR-CTV contouring, tile placement, and isodose registration. Applied to the clinical case, the module supported efficient iMRI import and the ability to drop, rotate, and translate tiles within the cavity interactively.

For any tile configuration, the module extracted full seed coordinates (local and RAS, mm) and the min–max axis-aligned bounding coordinates of the modeled 2D and 3D isodose surfaces (Table 1). Isodose surfaces overlaid on the iMRI let underdosed and overlapping regions be identified directly on the anatomy, showing where placement could be refined before closing (Fig. 2).

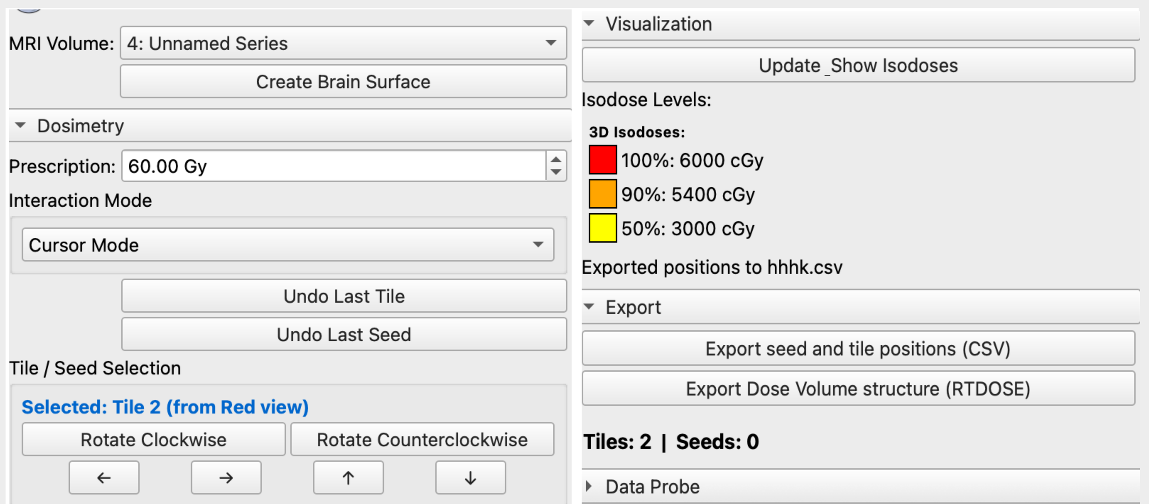

Figure 1. Control panel: prescription entry, interactive tile placement and rotation, isodose display (100%/90%/50% = 60/54/30 Gy), and CSV / DICOM RTDOSE export. Image by researcher.

Table 1. Extracted seed coordinates (local and RAS) and axis-aligned isodose bounding box for the modeled case (2 tiles, 8 seeds).

tile_index	seed_index	x_ras_mm	y_ras_mm	z_ras_mm	x_local_mm	y_local_mm	z_local_mm		
0	1	139.011841	20.318756	37.789752	-5.000000	-5.000000	0.000000		
0	2	135.368889	22.936638	28.852448	5.000000	-5.000000	0.000000		
0	3	136.190278	10.862799	36.170051	-5.000000	5.000000	0.000000		
0	4	132.547326	13.480680	27.232747	5.000000	5.000000	0.000000		
1	1	151.699438	53.740817	53.639637	-5.000000	-5.000000	0.000000		
1	2	151.370459	53.612062	43.645889	5.000000	-5.000000	0.000000		
1	3	149.011077	44.111314	53.852196	-5.000000	5.000000	0.000000		
1	4	148.682098	43.982559	43.858448	5.000000	5.000000	0.000000		
tile_index	center_x_ras	center_y_ras	center_z_ras	normal_x	normal_y	normal_z	seed_axis_x	seed_axis_y	seed_axis_z
0	135.779584	16.899718	32.511250	-0.958247	0.269625	0.095201	-0.364295	0.261788	-0.893730
1	150.190768	48.861688	48.749043	-0.958247	0.269625	0.095201	-0.032898	-0.012875	-0.999375
isodose_surface	dose_level_cGy	min_x_ras_mm	max_x_ras_mm	min_y_ras_mm	max_y_ras_mm	min_z_ras_mm	max_z_ras_mm		
Isodose3D_100%_6000cGy	6000.0	127.084480	157.368820	5.445960	59.253460	21.773218	59.198128		
Isodose3D_90%_5400cGy	5400.0	126.563309	157.950699	5.104187	59.726227	21.500870	59.588150		
Isodose3D_50%_3000cGy	3000.0	123.551292	161.579712	2.438187	62.721722	18.993521	62.393089		

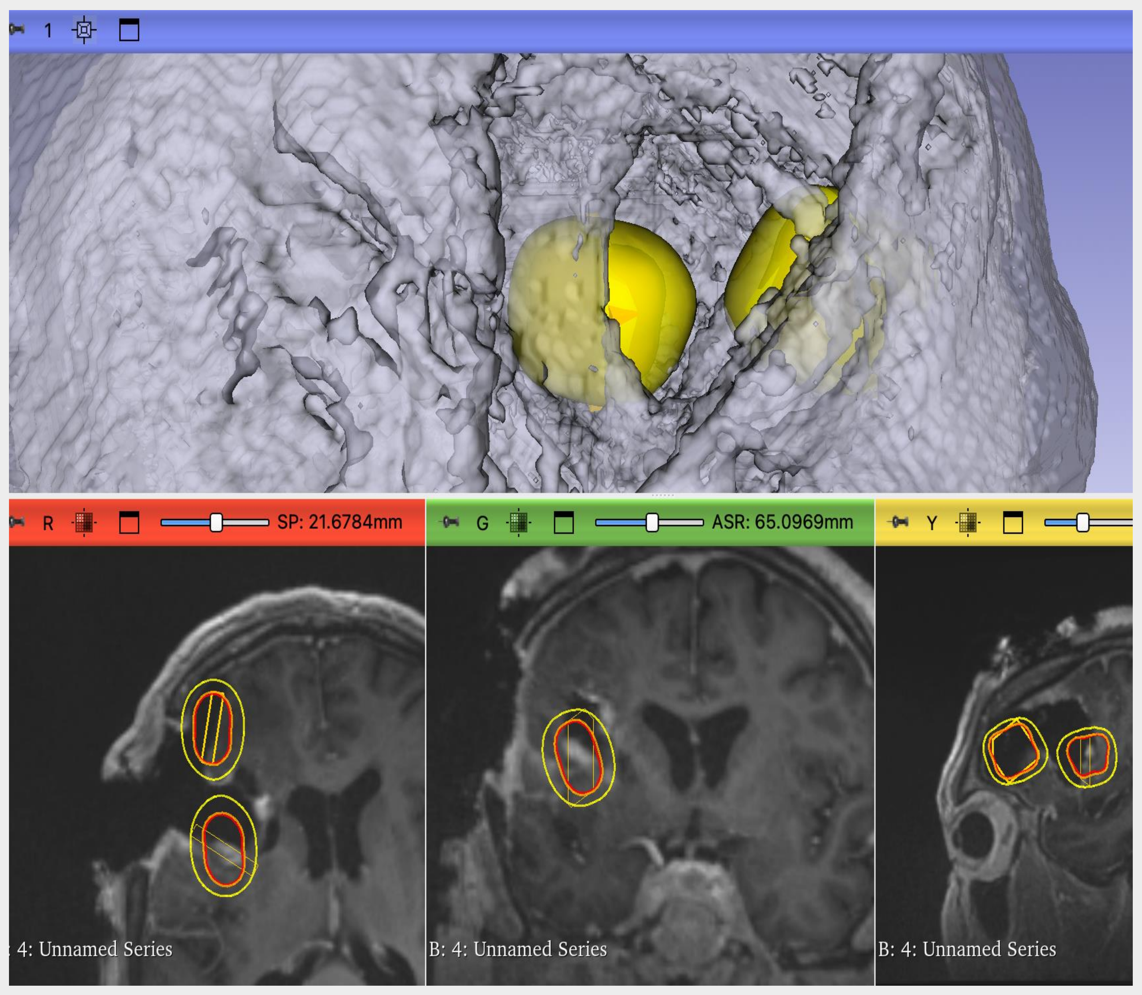

Figure 2. Modeled Cs-131 isodose distribution for the clinical case: 3D volume render (top) and axial / sagittal / coronal iMRI slices with 2D isodose contours (bottom). Red = 100% = 60 Gy; orange = 90% = 54 Gy, yellow = 50% = 30 Gy.

DISCUSSION

Currently, GammaTile dosimetry is confirmed only post-procedure, once brain shift and cavity deformation have already diverged from the pre-resection plan. By generating feedback while tiles/seeds are still adjustable, this workflow reframes intraoperative dosimetry from confirmation to decision support.

This retrospective proof of concept confirms the feasibility of using iMRI and a custom 3D Slicer module for GammaTile dosimetry evaluation, providing a low-cost, open-source framework for real-time dosimetry with full TG-43U1 modeling required for TPS (Ferreira et al., 2021) and DICOM RTDOSE export.

Limitations include a single-case cohort using simulated tile positions, not the implanted clinical plan. This study utilizes retrospective iMRI image since the optimal imaging modality for an intraoperative GammaTile intervention has not yet been finalized.

Figure 3. 3D-printed brain phantom with simulated resection cavity, used for ongoing imaging and workflow tests. Photo by researcher.

CONCLUSIONS

Future work includes finding the optimal workflow & setup with the ideal intraoperative imaging modality (e.g. MRI, CT, US, etc) (Fig. 3). The workflow would incorporate a treatment planning system similar to the proof-of-concept developed in this study. Further research on intraoperative GammaTile dosimetry is currently underway.

GammaTile is already a high-burden, high-stakes procedure, and current practice offers no intraoperative dosimetric feedback to guide tile positioning before dural closure. Clinicians have accordingly called for additional intraoperative guidance despite the workflow cost it imposes. This work offers valuable insight and proof of feasibility into a potential low-cost pathway toward closing that gap.

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