Developing a 4-D Dynamic Model for GammaTile Dose Distribution

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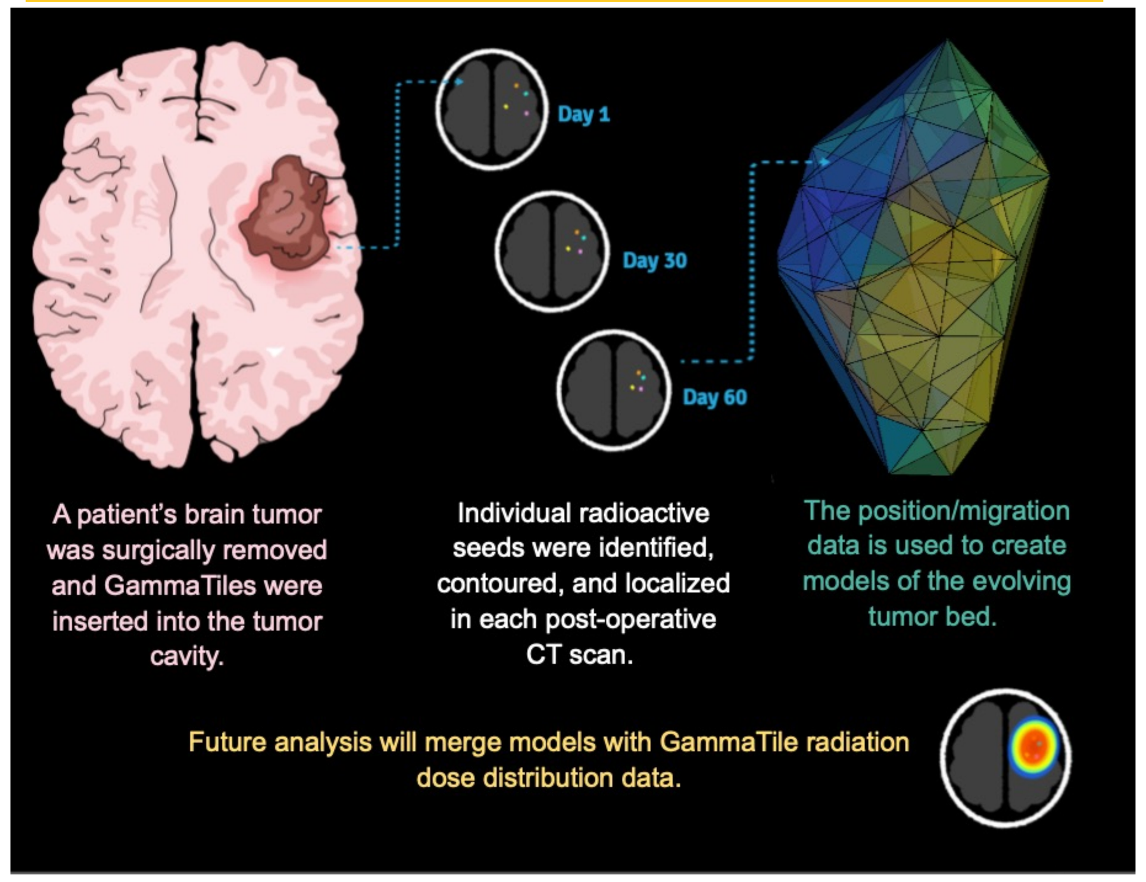
INTRODUCTION

- GammaTile brachytherapy, a novel and promising brain tumor treatment, involves the permanent implantation of radioactive Cesium-131 seeds into the brain immediately following the surgical removal of the tumor.
- Cesium-131 has a half life of 9 days, after 36 days a majority of therapeutic dose is delivered, at 100 days it is exhausted.
- The radiation sources are embedded with specific spacing to evenly dose the surrounding tumor cavity.
- The healing of the surgical cavity can result in the migration of the seeds and consequently the distribution of radiation dose.
- The above factors may warrant further consideration during the surgery planning process as they may alter:
  - the ultimate prescription dose with this treatment strategy
  - combination with traditional external beam radiotherapy (EBRT)

MATERIALS & METHODS



- A patient with glioblastoma received additional imaging after the implantation of their GammaTile radiotherapy sources as she was also receiving additional EBRT to the at-risk brain parenchyma surrounding the surgical cavity.
- Individual radioactive seeds were identified, contoured, and localized in each of the patient's post-operative CT scans.
- Tumor bed models were reconstructed using the triangulation of GammaTile seed positioning data and these models will be updated to display the 4-D evolution of the dose distribution.
- The contours were generated in Velocity™ (Varian Medical Systems, Palo Alto, California, USA) seed position models produced in Matlab® (Mathworks, Natick, Massachusetts, USA) and Meshlab (ISTI, Pisa, Italy, and CNR, Rome, Italy)

RESULTS

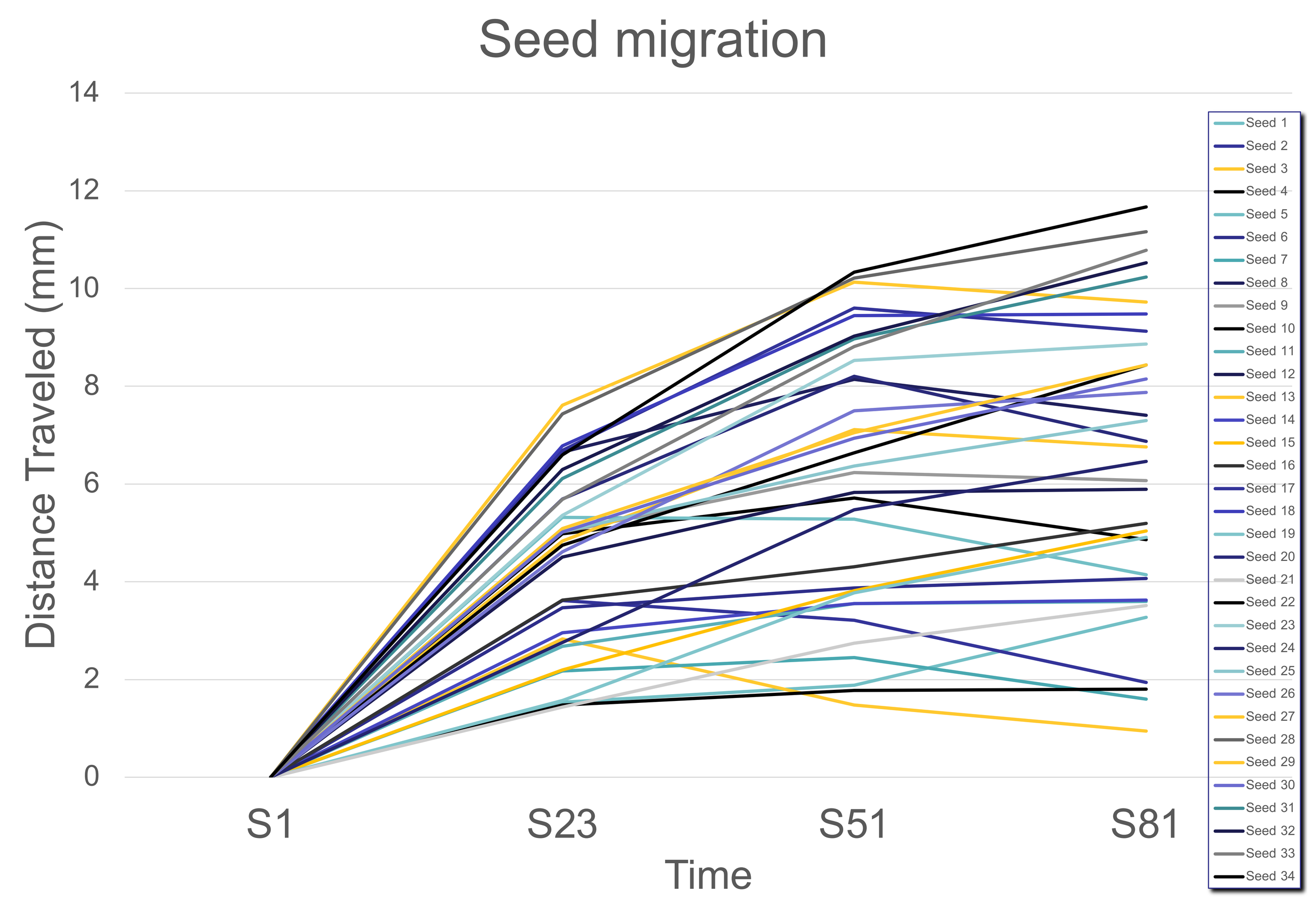


Figure 1
Plotted migration data for each GammaTile seed on the 1st, 23rd, 51st, and 81st day CT scans.

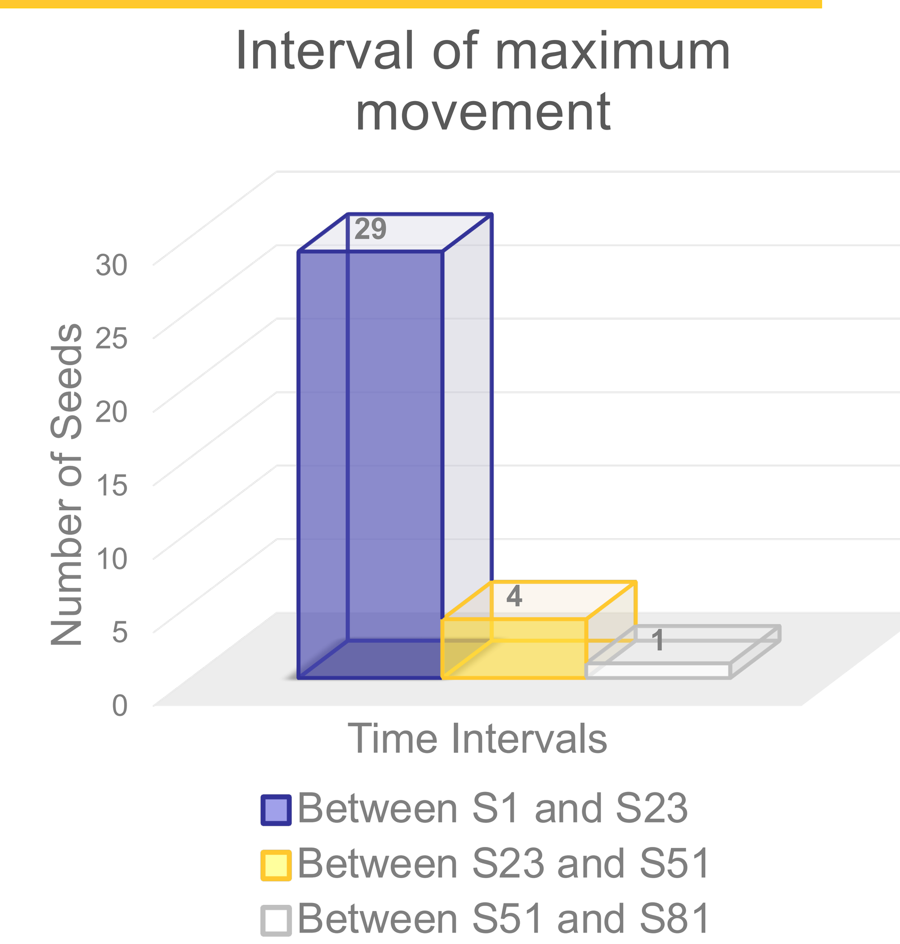


Figure 2
Count of the time interval where each GammaTile seed had its most migratory period.

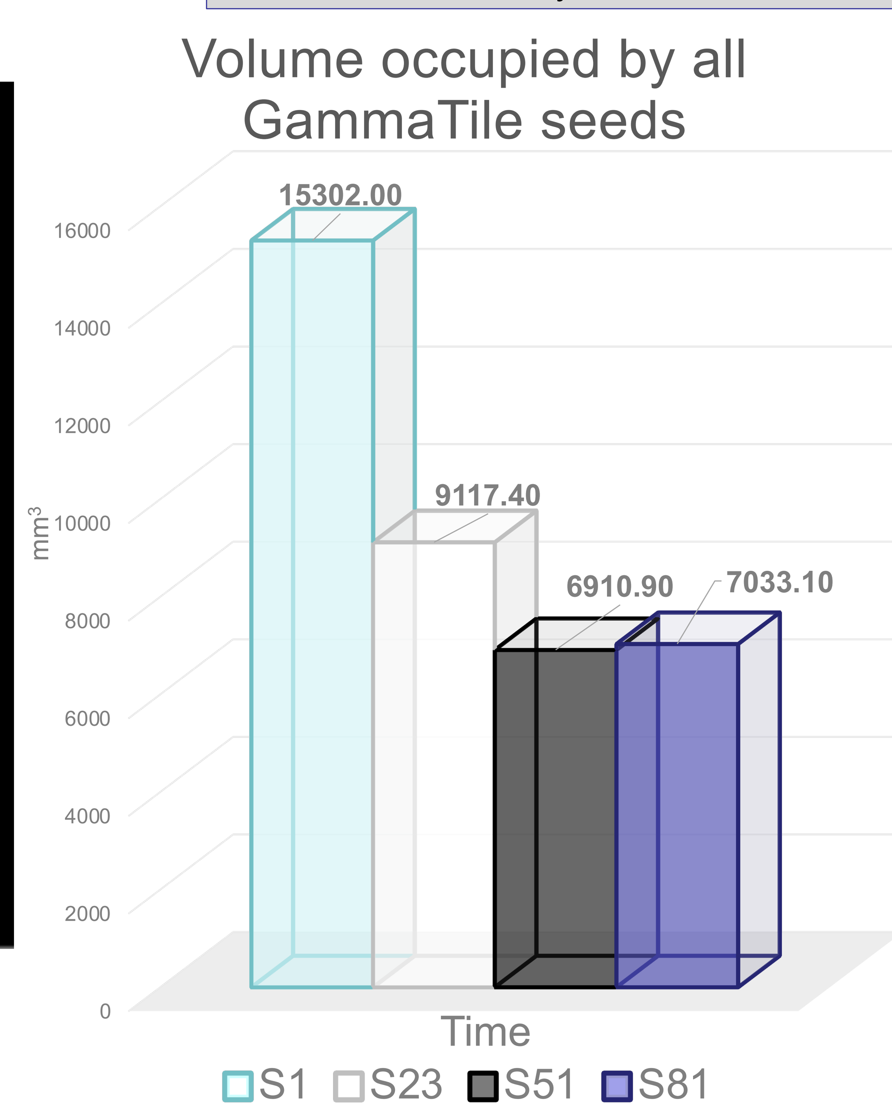


Figure 3
Volume occupied by all GammaTile seeds on the 1st, 23rd, 51st, and 81st day CT scans.

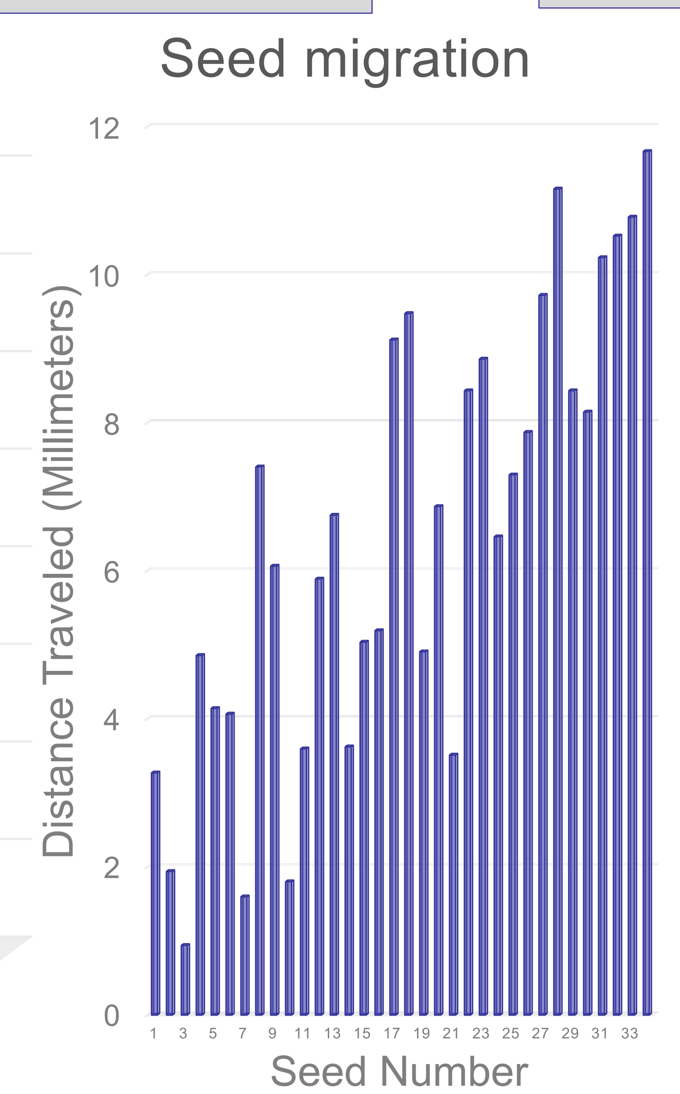


Figure 4
Plotted migration data for each GammaTile seed from the 1st through the 81st day CT scan.
Migration statistics:
- Mean - 6.46mm
- Median - 6.61mm
- Maximum – 11.67mm
- Minimum – 0.94mm

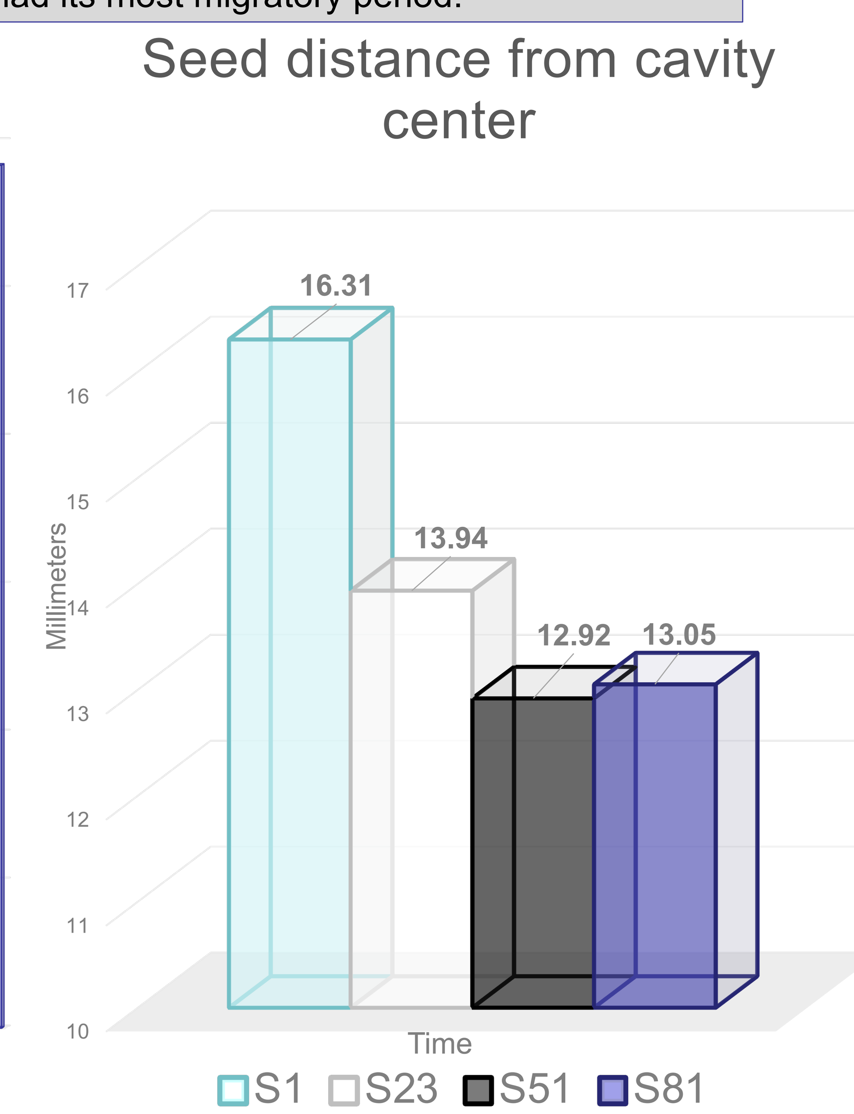


Figure 5
Positional data from GammaTile seeds in relation to their proximity to the tumor cavity's center.

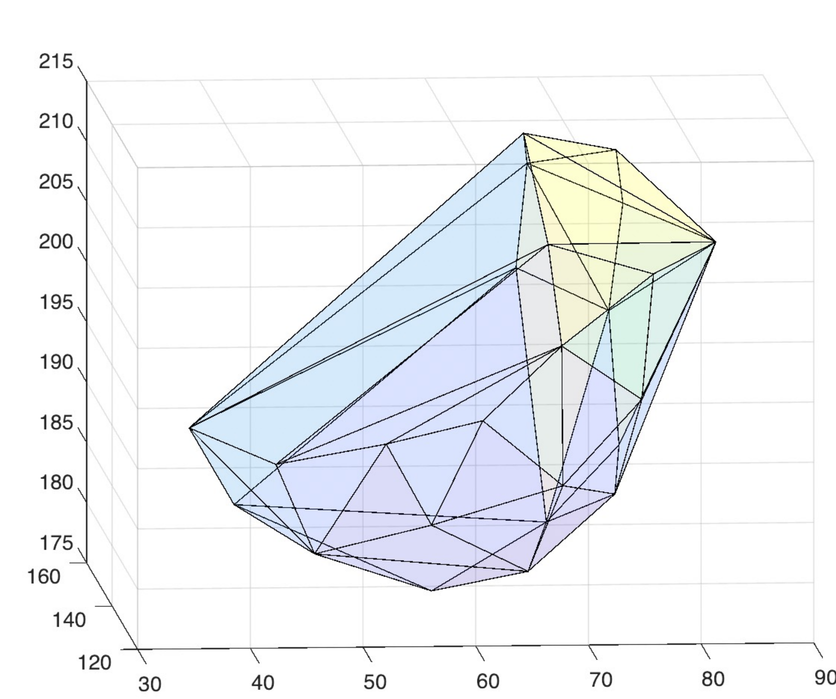
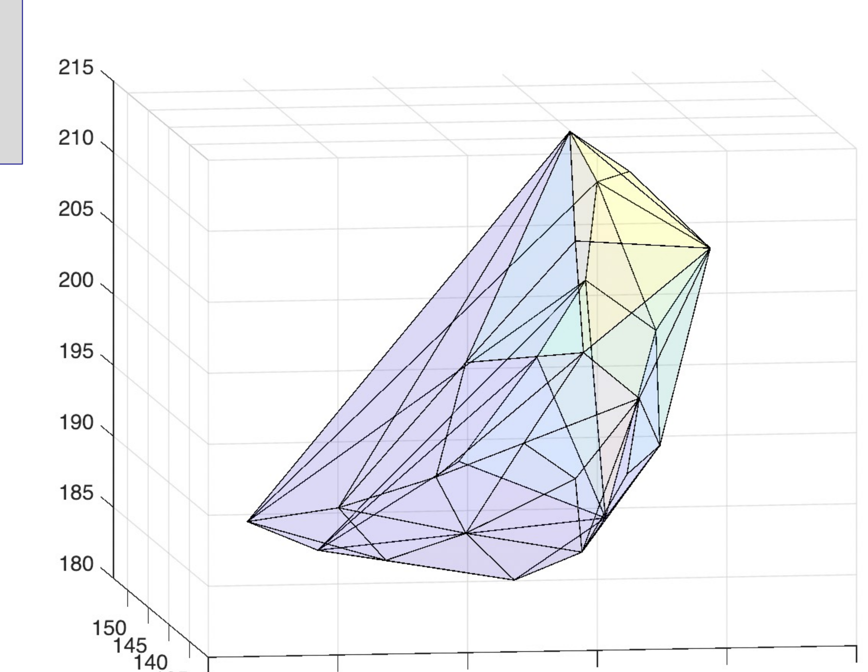


Figure 6
3-D reconstruction of the space occupied by all GammaTile seeds in the 1st (left) and 81st (right) day CT scans.



DISCUSSION

- The majority of GammaTile seed migration occurred within the first 23 days post surgery. However, further seed movement is seen through the 81st day *(Figures 1 and 2)*.
- The volume occupied by all GammaTile seeds is greatly reduced within the first 23 days post surgery. By day 51, the volume occupied is relatively stable *(Figures 3 and 6)*.
- GammaTile seeds that were placed in more inferior positions were more likely to migrate further distances overall *(Figure 4)*.
- As seeds traveled through the tumor cavity, over time they generally moved toward the center of the cavity *(Figure 5)*.
- All observations were seen in the scans of one patient.

Conclusions

- A majority of the radioactive seed movement occurred during the first 2.5 half lives which is when most of the radiation dose was distributed.
- The seeds remained within the surgical cavity and tended to move centrally within the cavity as the cavity itself shrunk over time.
- Future studies will look at how the density of dose delivered changes over time in relation to changes in the planned target volume over time. The finding of the future work may indicate that less dose is required at time of surgery to achieve the desired overall dose to the planning treatment volume.
- Future studies would involve an expanded patient population.

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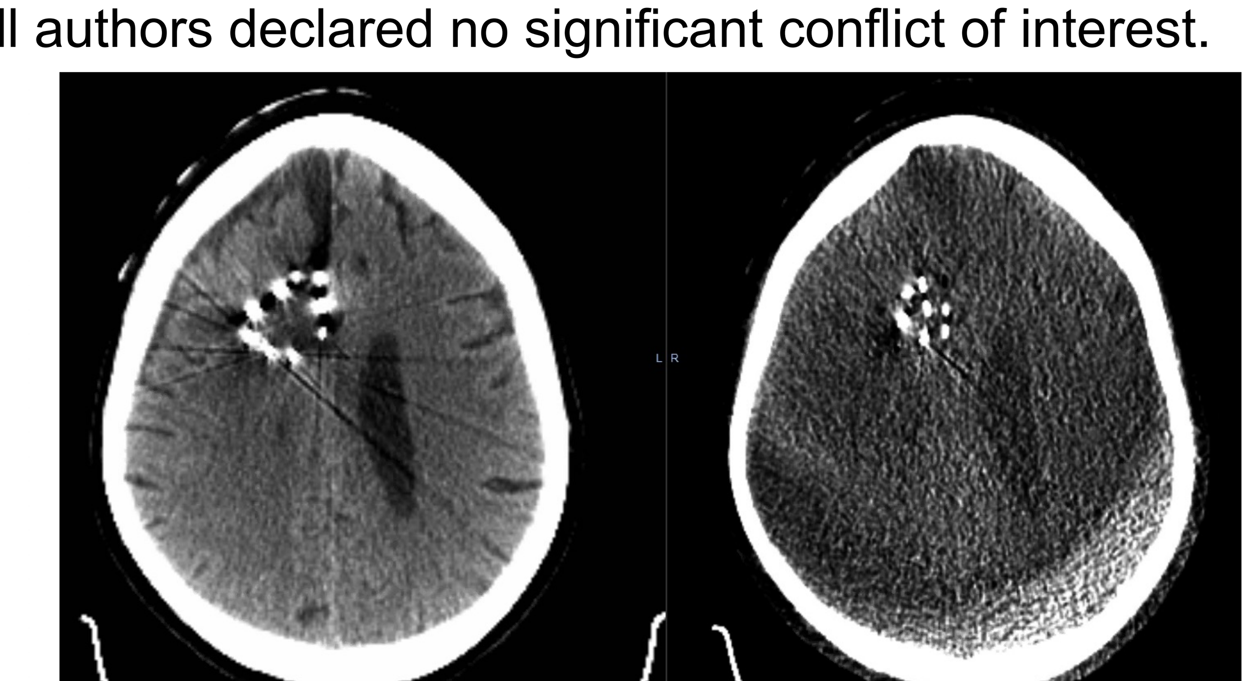

Head CT scans with implanted GammaTile seeds