An Evidence-Based Evaluation of Lesion Size and Distance Criteria for Rotational Error Mitigation In Single-Isocenter Multi-Target (SIMT) Radiosurgery

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Introduction

- Brain metastases occur in **20 to 40% of patients with cancer** [1]
- Stereotactic Radiosurgery (SRS) is preferred in surgically inoperable patients with limited metastases
- In comparison to treating a single lesion at isocenter, the use of **Single-Isocenter Multi-Target (SIMT) to treat multiple lesions increases the treatment efficiency.** However, this technique is **more sensitive to rotational errors**, which can affect the delivered dose distribution [2]
- The aim of this study was to provide evidence-based distance and size criteria to create robust SIMT plans based on simulated residual setup errors
- Additionally, we aimed to develop **an institution-specific automated algorithm for SIMT plan preparation** to mitigate rotational errors due to lesion size (LS) and distance-to-isocenter (DTI)

Methods

- **6 Patients with 51 brain metastases** were retrospectively included in the study. The lesion cohort was divided using an 80/20 split for training and testing
- A **1° rotational error was introduced for each GTV** using the Eclipse Plan Uncertainty Parameter function **(Figure 1)**
- A Logistic regression model was trained to use lesion size (LS) and distance-to-isocenter (DTI) to **predict D99% being less than 95% (D99%<95%) after a simulated rotation**
- Model performance was assessed on the training and testing cohorts, and **an optimal operational point** was chosen on the training cohort based on the AUC
- A decision boundary to define the probability a lesion experiences D99%<95% after a 1° rotation using DTI and LS was determined using the optimal threshold
- A **grid search optimization algorithm was developed** to search through 3D space and define the number and location of isocenters, as well as no. of PTV margins, necessary to generate a plan robust to 1° rotational uncertainties based on the generated decision boundary

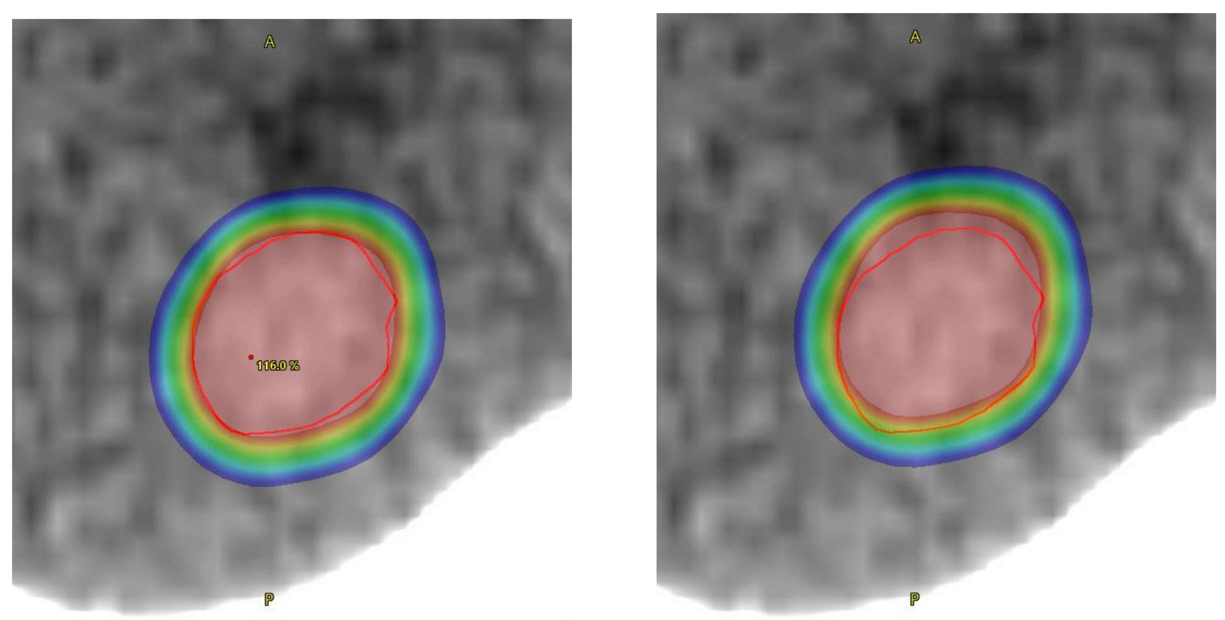

Figure 1: Original dose distribution (left) and dose distribution with added 1° rotational uncertainty (right).

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Results

- The patient cohort consisted of a median of 4 lesions per plan (3-12), with a median DTI of 2.83 cm (0.80– 6.63cm) and a median LS of 0.17cc (0.01 - 13.63cc)
- The model achieved an **AUC of 0.86 and 0.82 on the training and testing cohorts** respectively when predicting D99%<95% using LS and DTI **(Figure 2)**

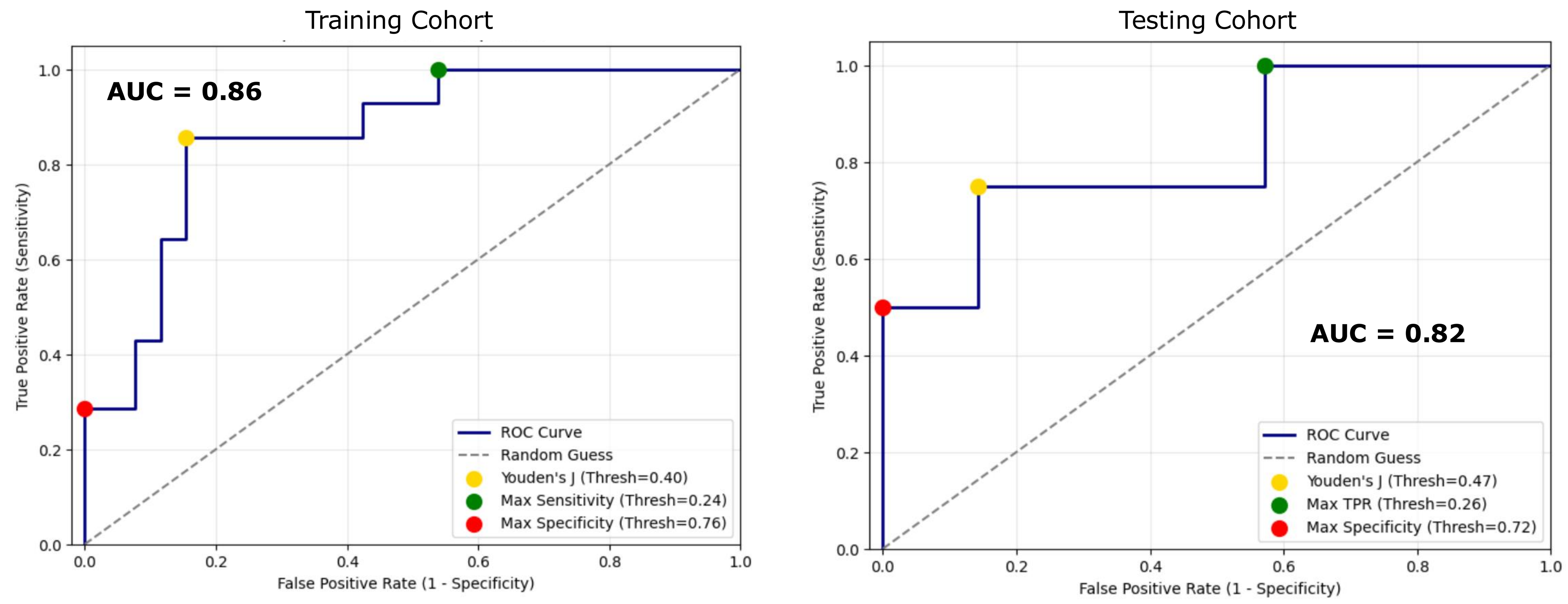

Figure 2: AUC for the training and testing cohorts when using LS and DTI to predict D99%%<95% after an induced 1° rotation.

- The decision boundary determined that lesions experience D99%<95% when targets are: **< 1cc and > 4.3cm from iso, 1-2ccs and > 4.5cm from iso, 2-5ccs and > 4.8cm from iso, and >5cc and > 5.5cm from iso** **(Figure 3)**
- The optimization algorithm **balances efficiency and plan robustness** to determine the optimal configuration **(Figure 4)**

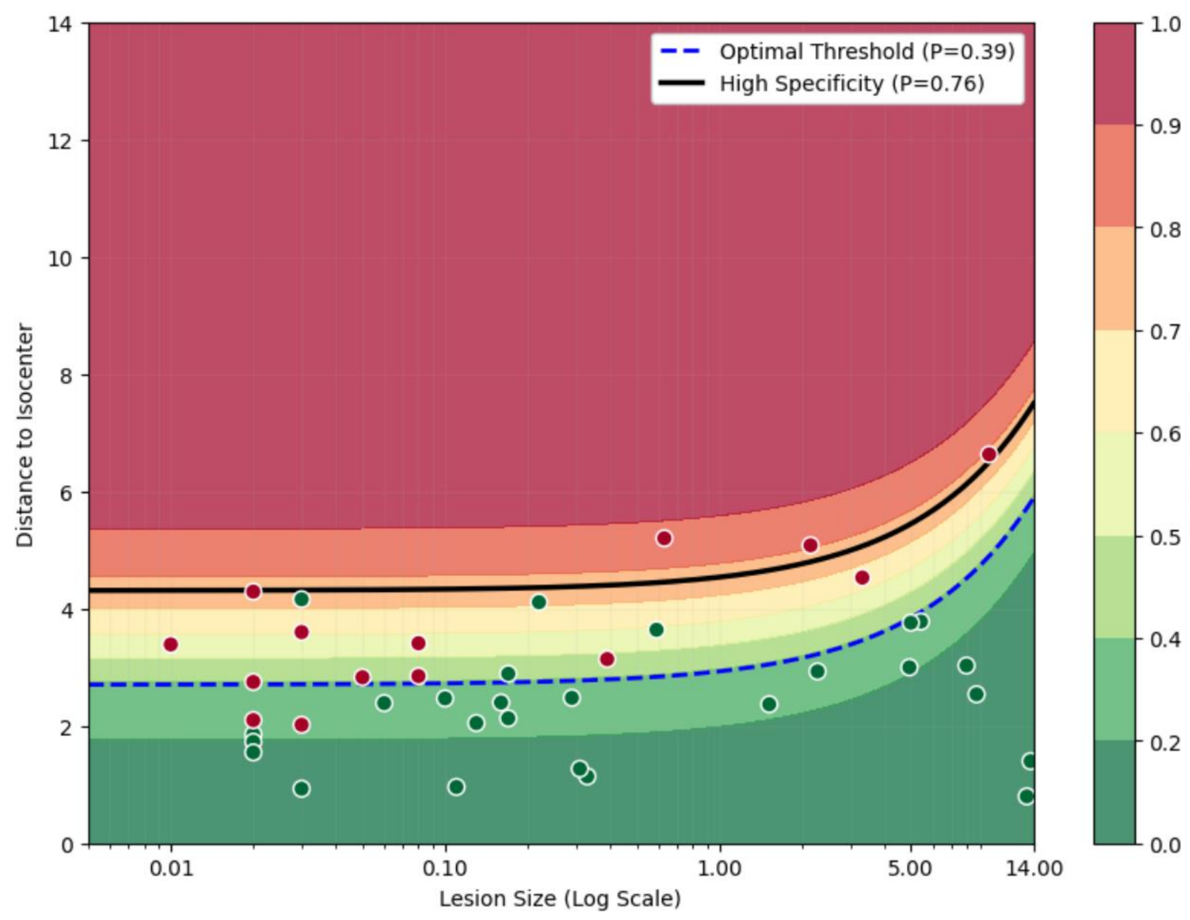

Figure 3: Decision boundary using DTI and LS to determine the probability a lesion experiences D99%<95% after a 1° rotation

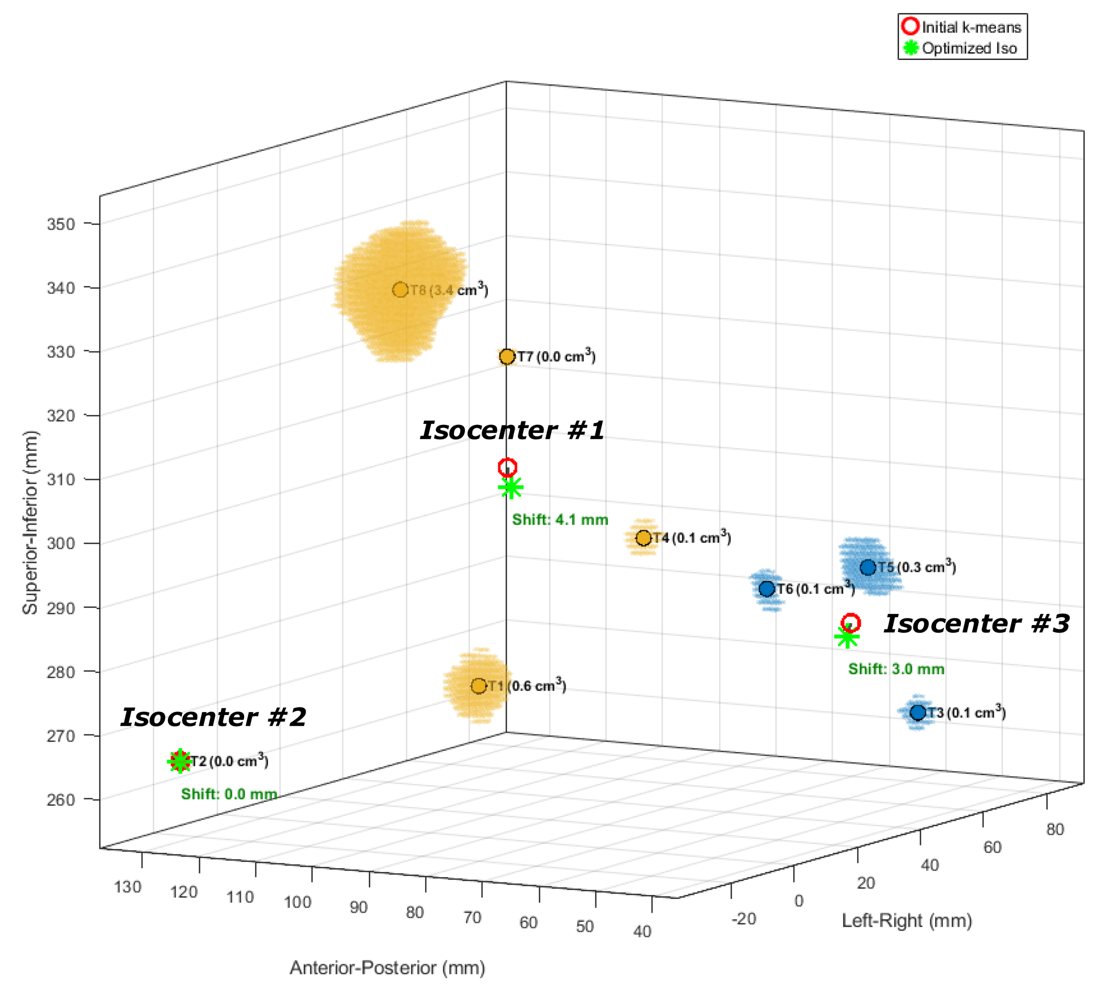

Figure 4: Determined optimal plan configuration for a patient with 8 brain metastases.

Discussion

- This process can be used at our institution to assess the need for PTV margins on a per-case basis, to maintain tumoricidal coverage
- The developed optimization algorithm automatically determines the optimal target clusters, number of isocenters, and isocenter location while accounting for treatment efficiency and robustness to rotation errors (i.e., isocenter closer to smaller lesions that are more sensitive to rotation errors). This minimizes the risk of undercoverage
- The algorithm takes ~10 seconds to run, has been successfully implanted into Eclipse via ESAPI scripting, and **improves on current automated SIMT planning methods in speed and utility** [3,4]

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Conclusion

- These results **demonstrate that LS and DTI can be used to accurately predict a potential decrease in target coverage** due to rotational uncertainty using a simple logistic regression model
- Additionally, it demonstrates a potential automated clinical workflow to make SIMT planning more efficient, robust, and planner-agnostic

References

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