Improving the Conformity of SSRS Treatment Plans in Lumbar and Thoracic Spine in RayStation

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ABSTRACT

- Our study evaluated a planning pattern for conforming doses in Stereotactic Spine Radiation Surgery (SSRS) plans in RayStation intended to improve the efficiency and consistency of the planning process. This approach for Volumetric Modulated Arc Therapy (VMAT) initially prioritizes organs at risk (OAR) constraints and target coverage objectives and then maximizes the dose conformity. We retrospectively applied this patterned approach to 10 clinical cases and measured the ratio between the target coverage versus dose to the OAR.

- All plans were initially optimized with identical planning structures and objectives. Beams were arranged in four half arcs (182-262) and (96-178) with collimator angles at 90. The target's min dose objectives were at a weighting of 80 for the first 200 iterations, while the weights for the spinal cord/ cauda equina maximum dose objectives were 100 and the gross tumor volume (GTV) min objective weight was set to 5. The other OAR objectives and planning structures were kept at a low weighting of 1 or 0.5, and the optimizer was run for 200 iterations. After 200 iterations, the planners raised the weights of the OAR and target objectives and ran the optimizer for another 200 iterations. After an additional 200 iterations, the planners increased the weights of the target minimum dose objectives to optimize the coverage. The dosimetrist tuned the dose normalization to optimize coverage.

- Compared to the original plans, this systematic planning approach yielded similar target coverage and dose to OARs with improved conformity.

Keywords: Stereotactic Spine Radiosurgery, SSRS, conformity, coverage, conformity index, plan quality

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INTRODUCTION

- In Stereotactic Spine Radiation Surgery (SSRS) a highly conformal, ablative dose is delivered to tumors while sparing the surrounding healthy tissue. The challenge in treatment planning is to balance dose conformity with target coverage and dose to organs at risk (OARs). The tradeoff is between a plan with the prescribed dose conformal to the target volumes and one with steep dose gradients between the targets and adjacent OARs.
- Steep gradients in some regions result in a loss of conformity in others. Conversely, emphasizing high conformity can reduce the target coverage or increase the dose to OARs. When evaluating the quality of SSRS plans, it is difficult to determine if the optimal balance has been achieved. Emphasizing conformity too much or too little leads to re-planning, which is time-consuming and can lead to patient treatment delays. Thus, there is a need for generalizable treatment planning methods that optimize this tradeoff.
- The purpose of our study was to evaluate a planning pattern for conforming doses in Stereotactic Spine Radiation Surgery (SSRS) plans in RayStation intended to improve efficiency and consistency of the planning process. We based our planning pattern the objective of initially prioritizing organ at risk (OAR) constraints and target coverage objectives, and then maximizing the dose conformity.

METHODS AND MATERIALS

- 10 clinical SSRS plans were chosen based on these qualifications: plans challenging to reach conformity and for only the lumbar and thoracic spine levels. With these ten plans selected, the objective was to re-plan them using a guideline that can generate a plan as close to the approved plan as possible without further fine-tuning
- Plan setup and objectives:

Beam	Gantry Start	Gantry Stop	Rotation
Beam A	182	262	Clockwise
Beam B	262	182	Counterclockwise
Beam C	96	178	Clockwise
Beam D	178	96	Counterclockwise

Table 1: Beam arrangement and gantry angles of Testing Approach

ROI	Function	Description	1st 200 iterations weight	2nd 200 iterations weight	3rd 200 iterations weight
pGTV	Uniform dose	2448 cGy	1	50	50
pGTV	Min dose	2448 cGy	80	100	120
pCTV	Min dose	1600 cGy	80	100	120
pGTV 2400_min 1500	Min dose	1500 cGy	80	100	120
GTV ring	Max DVH	2304 cGy	1	20	20
CTV ring	Max DVH	1536 cGy	1	20	20
pCTV outer ring	Max dose	750 cGy	0.5	2	2
Cauda Equina (lumbar cases only)	Max dose	1400 cGy	100	120	150
Cauda Equina (lumbar cases only)	Max EUD	1100 cGy	20	50	50
Spinal Cord	Max dose	1100 cGy	100	120	120
Spinal Cord	Max EUD	900 cGy	20	50	50
Fs NT	Max dose	1300 cGy	0.5	2	2

pGTV/; planning gross tumor volume; pCTV: planning clinical tumor volume; DVH: dose-volume histogram; EUD: equivalent uniform dose

Table 2: RayStation Objectives and Weighting increments

RESULTS

Thoracic

- GTV coverage: The re-planned's mean was 84.898. The clinical's mean was 86.704. Δ1.806
- GTV CI*:* The re-planned achieved a higher CI with a mean of 0.804. In contrast, the clinical yielded a mean of 0.712.
- CTV coverage*:* the re-planned mean yielded at 96.47, whereas the clinically approved was 97.27. Δ 0.8.
- CTV CI: the re-planned had a higher value of CI (0.606) than the clinical plans (0.56)
- Spinal Cord*:* An average dose was 1117 cGy for the treated plans and 1238.4 cGy for re-planned cases.

Lumbar

- GTV coverage*:* Approved plans and re-plans had 0.106% in favor of the approved plans.
- GTV CI: The average of previously treated was 0.814, while the re-planning achieved an average at 0.882.
- CTV coverage: The approved was 98.428 on average, and average re-planned CTV coverage was 97.582
- CTV CI: The planning pattern achieved a higher mean (0.724) than the clinically approved (0.71)
- Cauda Equina*:* Similar result. <1600 cGy on average

Location	Spinal Cord Dose (cGy)		GTV 2400 Coverage (%)		CTV 1600 Coverage (%)	
	Clinically Approved	Planning Pattern	Clinically Approved	Planning Pattern	Clinically Approved	Planning Pattern
T7	1066	1088	98.01	96.44	96.85	96.87
T1	1215	1440	72.02	73.67	95.99	95.68
T5	993	1325	88.72	83.14	96.53	97.4
T4	1100	1177	90.42	85.95	97.67	95.71
T5	1211	1162	84.53	85.35	99.31	96.69

Table 3. Dose received from the Spinal Cord and the percentage of GTV and CTV coverage between Clinically Approved plans versus Testing Approach plans for the Thoracic Spine

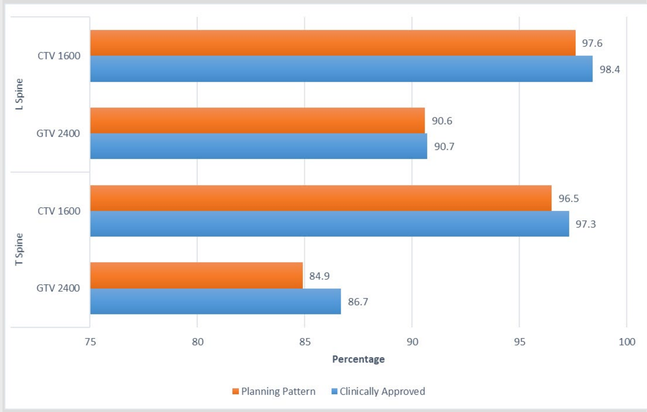

Chart 1: The mean percentage of GTV and CTV Coverage in T Spine and L Spine

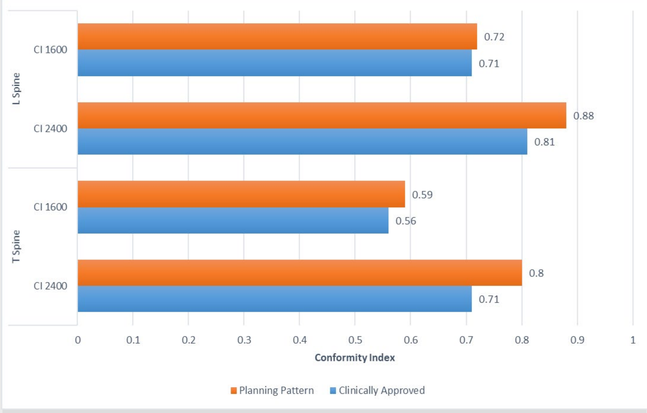

Chart 2: Mean Conformity Index of 2400 cGy and 1600 cGy in T Spine and L Spine

DISCUSSION

- As the population standard deviation is unknown, the data is assumed to be normally distributed, and the two-sample T-Test (one tail) can be applied to analyze the data that were collected in for the Thoracic Spine and the Lumbar Spine.
- The null hypothesis for Two Sample T-Test Equal Variance is that the performance means from Clinical Approved plans and Testing Approach plans are equal:

$$H_0: u_1 = u_2,$$

- And the alternative hypothesis proposes Testing Approach plans have better performance than Clinical Approved plans

$$H_A: u_1 < u_2$$

- Where u_1 = mean performance of Clinical Approved plans & u_2 = mean performance of Testing Approach plans
- The test set a significant level (also called alpha) that allowed us to either reject or accept the alternative hypothesis at 0.05.
- Our study failed to reject the null hypothesis for Thoracic Spine since Table 5 showed that p-values from Spinal Cord Dose, GTV 2400 Coverage, and CTV 1600 Coverage were greater than the level of significance (0.05). Hence, performance is the same between Clinical Approved and Testing Approach plans.

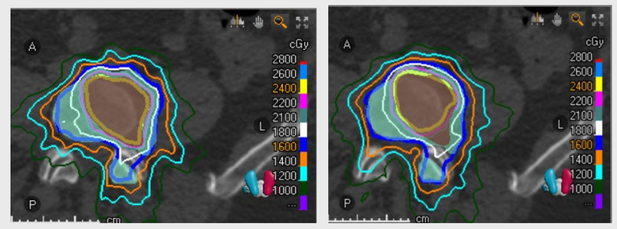

Fig. 1. An example of an axial view comparison of improved conformity index of 2400 cGy and 1600 cGy in L-Spine using the Testing Approach (left) versus Clinical Approved (right).

CONCLUSIONS

- Constructed a planning pattern that could improve conformity without impacting the GTV coverage or dose to the organs at risk for SSRS plans.
- The approach used on re-planned cases was quick to complete.
- A planner can achieve an SSRS plan that is close to being clinically approved without any fine tuning. With this planning pattern, the planners have the freedom to further optimize their plans based on the clinical directives given at their clinics.
- Limitations:
  - With a small sample size, the statistical power of the t-test decreases..
  - Increased likelihood of Type II errors
  - Outliers can have a significant impact on the results of the t-test.
  - With small sample sizes, these assumptions may not hold, leading to inaccurate results.

REFERENCES

RSL-D-RS-11B-OPT-EN-1.0-2021-12-10 Raystation 11B a Guide to Optimization in Raystation