Development and Validation of a RapidPlan™ Model for Streamlining Clinical Craniospinal VMAT Irradiation Planning

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Introduction

Figure 1: Sagittal view of a VMAT total CSI plan

Craniospinal Irradiation (CSI) is a form of radiation therapy that delivers dose to the brain and entire spinal canal. Historically, CSI was treated with lateral fields for the brain, and AP and/or PA fields for the spine. Modern techniques using static IMRT or VMAT with auto-feathering techniques have been developed to improve dose conformality, thereby sparing more normal tissue.

Due to the nature of these cases, the planning time window is often constrained, and the use of inverse optimization requires time.

For this study, a RapidPlan™ (v16.1, Varian Medical Systems, Palo Alto, CA) knowledge-based model was created to assist in reducing the planning time and tested by a group of dosimetrists to assess time savings.

Methods

- Twenty-one patients were retrospectively selected for inclusion in the RapidPlan™ knowledge-based model. Version: 16.1.2 of Eclipse
- A CSI VMAT plan was created for each patient in Eclipse (Varian Medical Systems, Palo Alto, CA) for a TrueBeam linear accelerator equipped with a Millenium 120 MLC.
- Each plan consisted of three isocenters: brain, upper spine, lower spine. The brain isocenter utilized three full arcs (6 or 10 MV), while the upper spine and lower spine plans each utilized two arcs (10 MV).
- All 3 isocenters were optimized in a single plan with autofeathering using P.O. 16.1, **Figure 2.**
- The final plan was divided into three plans (Brain, Upper Spine, Lower Spine) for delivery purposes.
- The Y jaws were adjusted to overlap by approximately 5 cm. in order to utilize the autofeathering properly. See **Figures 3 and 4** for beam geometry.

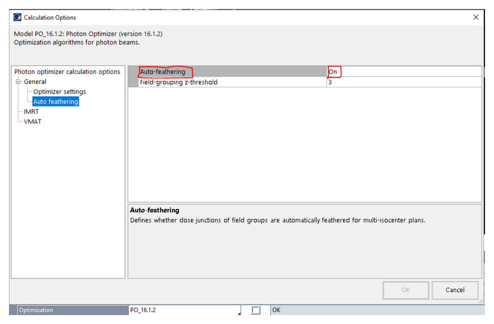

Figure 2: Autofeathering settings in calculation model P.O. 16.1.2

Group	Field ID		Coll Rtn [deg]	Couch Rtn [deg]	Wedge	Field X [cm]	X1 [cm]	X2 [cm]	Field Y [cm]	Y1 [cm]	Y2 [cm]
I	01 CCW 179-181	- 6X	330.0	0.0	None	15.0	+10.0	+5.0	30.0	+14.0	+16.0
I	02 CW 181-179	- 6X	30.0	0.0	None	15.0	+5.0	+10.0	30.0	+14.0	+16.0
I	03 CCW 179-181	- 6X	10.0	0.0	None	15.0	+6.0	+9.0	30.0	+12.0	+18.0
II	04 CW 181-179	- 10X	350.0	0.0	None	15.0	+7.5	+7.5	33.0	+17.0	+16.0
II	05 CCW 179-181	- 10X	10.0	0.0	None	15.0	+7.5	+7.5	33.0	+17.0	+16.0
III	06 CW 181-179	- 10X	350.0	0.0	None	15.0	+7.5	+7.5	36.0	+19.0	+17.0
III	07 CCW 179-181	- 10X	10.0	0.0	None	15.0	+7.5	+7.5	36.0	+19.0	+17.0

Figure 3: Beam geometry settings

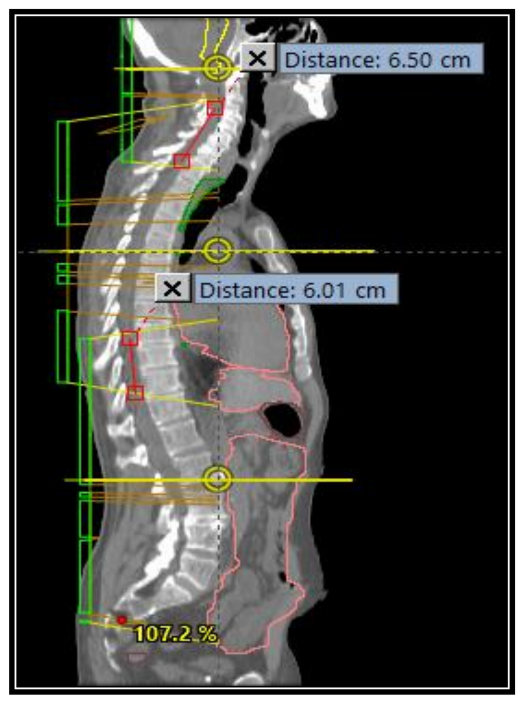

Figure 4: Overlap region with jaws

- To avoid dosimetric uncertainty from treating through the arms, avoidance sectors were utilized.
- Avoidance sectors were consistent in all plans: 240-310 and 50-120 degrees were used for the upper and lower spine isocenters of every patient.
- Avoidance sectors also helped to minimize the lung dose.
- No avoidance was used for the brain isocenter.

Avoidance Sectors & Optimization Structures

- Four optimization structures were created in to achieve optimal normal tissue sparing and conformity, **Figures 5-8** show the 4 optimization structures.

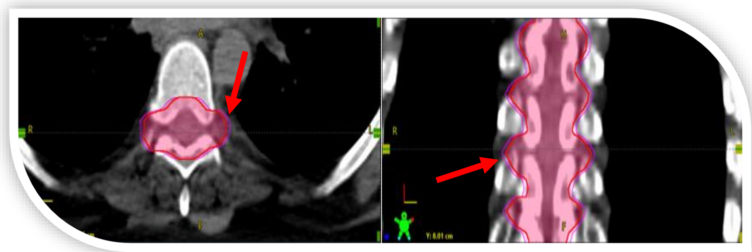

***Figure 5*: OptiPTVSpine-** 1 mm. expansion laterally ONLY on the PTV Spine

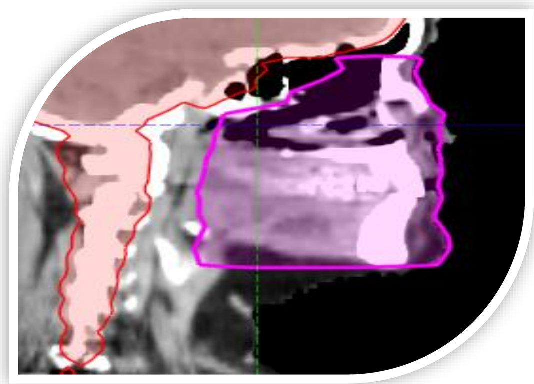

***Figure 6*: Avoid Face-** From top of orbits to bottom of chin; 2 cm. cropped from the PTV Total CSI

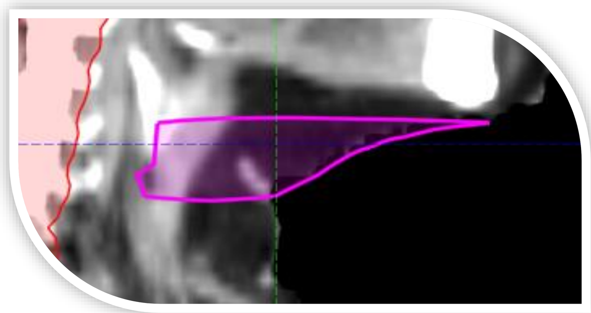

***Figure 7*: Avoid Throat-** From bottom of chin to top of suprasternal notch; 2 cm. cropped from the PTV Total CSI

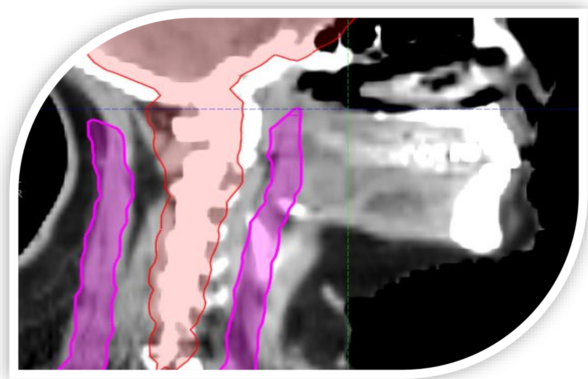

***Figure 8*: Ring-** A ring encircling the PTV Spine, 1 cm. away from this volume, assisted with high dose conformity

Total CSI Model Structures and Objectives

- The primary objective during optimization was to provide adequate target coverage: V100>90% for all 3 PTV's, Figure 10. The D90% and D95% were controlled as to not protrude into the vertebral bodies, to spare bone marrow.
- Once each plan was completed for each patient, it was uploaded to the model.

Table 1: Optimization Objectives in the RapidPlan

Model Structure	Code	Objective	Volume (%)	Dose (%)	Priority
PTV Brain	(PTV_High)	Upper	0	103%	125
		Lower	100	100%	135
		Lower	98	100%	135
		Upper gEUD		100%	65
		Target gEUD		100%	65
PTV Spine	(PTV_High)	Upper	0	103%	125
		Lower	100	100%	135
		Lower	98	100%	135
		Upper gEUD		100%	65
		Target gEUD		100%	65
OptiPTVSpine	(PTV_High)	Upper	0	103%	125
		Lower	100	100%	135
		Lower	98	100%	135
		Upper gEUD		100%	65
		Target gEUD		100%	65
PTV Total CSI	(PTV_High)	Lower	100	100%	135
		Lower	98	100%	135
		Upper gEUD		100%	65
		Target gEUD		100%	65
Avoid Face	(Control)	Mean	0	30%	100
Avoid Throat	(Control)	Mean	0	30%	100
		Mean		Generated	45
Esophagus	(7131)	Mean		Generated	50
Heart	(7088)	Mean		Generated	85
		Line (preferring OAR)	Generated	Generated	60
Kidney_L	(7205)	Mean		Generated	50
Kidney_R	(7204)	Mean		Generated	50
Larynx	(55097)	Mean		Generated	55
Parotid_L	(59798)	Mean		Generated	50
Parotid_R	(59797)	Mean		Generated	50
Ring	(13889)	Mean		Generated	100
		Upper gEUD	75%	65	30
		Line (preferring OAR)	Generated	Generated	100
SpinalCord	(7647)	Upper	0	99%	100

Discussion – Sample Size

- Due to the rarity of these cases, only 15 cases were found dating back to 2011.
- A creative method where the Brain was virtually reconstructed allowed us to expand our sample set: 6 patients treated for Total Lymphoid Irradiation, where the entire spinal cord and half the brain had been scanned, were modified and planned for CSI. See **Figure 9**.

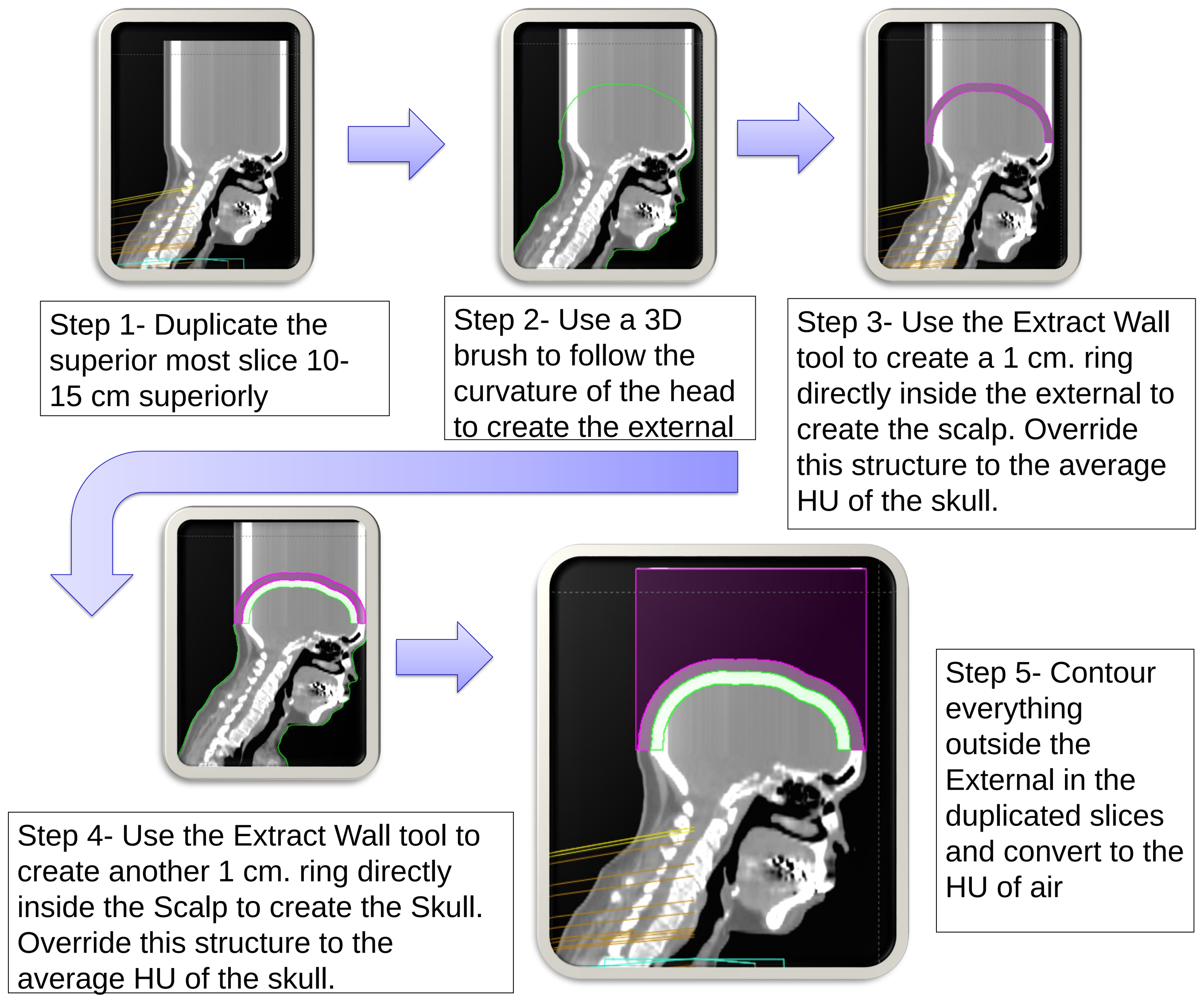

Figure 9: Steps to create a virtual brain to increase sample size.

Discussion – Time Savings

- Prior to use of the RapidPlan model, it would take multiple days to plan these cases due to the large calculation volume.
- A minimum of 15 optimizations were typically required before an optimal, treatable plan that met the physician's requirements, could be achieved.
- Two independent dosimetrists were able to create optimal plans in approximately 5 optimizations.
- This model has now been utilized on live clinical plans, where a plan that would initially take multiple days, took only one day.

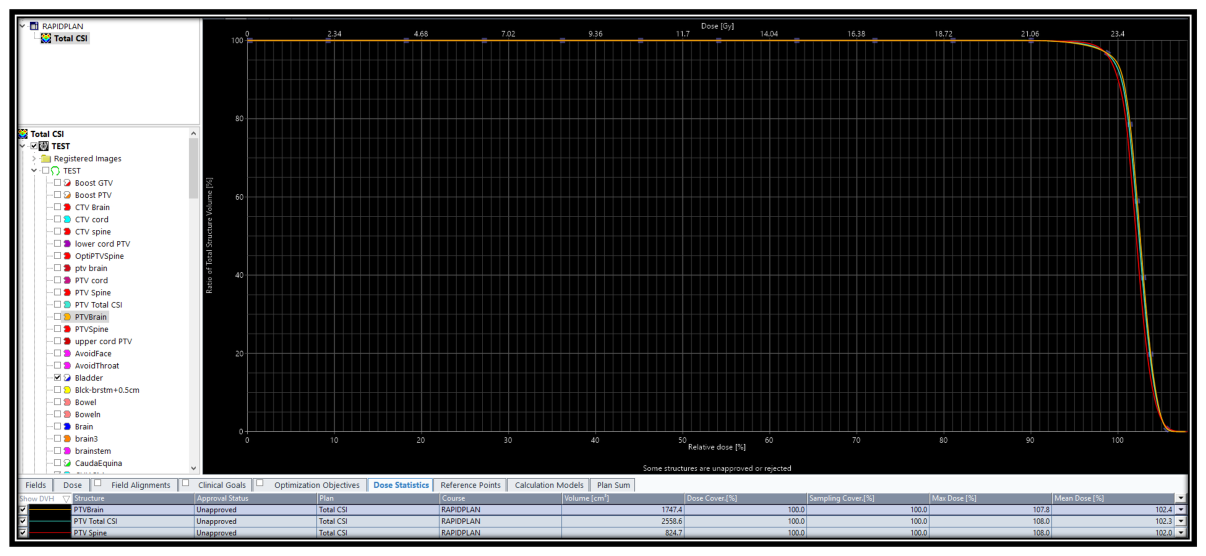

Figure 10: DVH with all 3 PTVs (PTVSpine, PTVBrain, and PTV Total CSI) receiving a V100 of at least 90%

Conclusion

- Due to the infrequency of CSI cases and large calculation volume, it can be challenging even for an experienced planner to create an optimal VMAT plan with a quick turnover period.
- Multiple dosimetrists validated the RapidPlan on numerous patients demonstrating optimal plans could be created in a shorter duration.
- The use of a RapidPlan for VMAT Total CSI has resulted in decreased planning time.

Learning objectives:

1. The reader will be able to describe the 3 isocenter technique used for total CSI VMAT planning.
2. The reader will be able to describe the optimization structure used to create a conformal dose distribution.
3. The reader will be able to explain how a RapidPlan model can be used to decrease multiple plan iterations.

References:

1. Roshan S. Prabhu, et al. Volumetric Modulated Arc Therapy (VMAT) Craniospinal Irradiation (CSI) for Children and Adults: A Practical Guide for Implementation, Practical Radiation Oncology, Volume 12, Issue 2, 2022, Pages e101-e109.

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