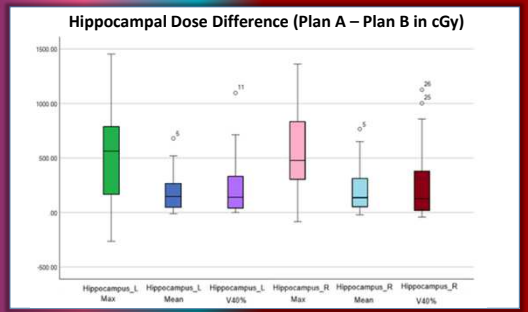
Craniopharyngioma Proton Plans: Evaluating Addition of Eclipse NTO to Ring-Only Optimization

Sarah Johnson M.S., CMD, RT(T)
Cincinnati Children's/UC Health Proton Therapy Center
Sarah.Johnson2@cchmc.org

Introduction

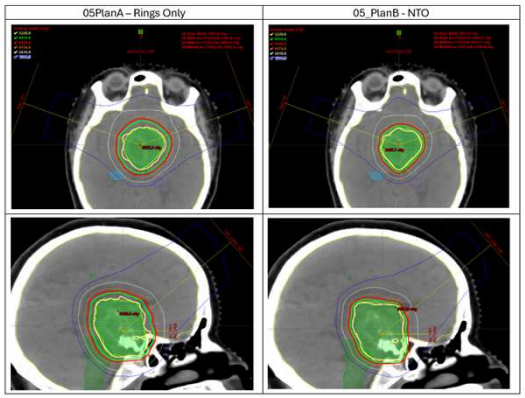
Craniopharyngiomas present unique dosimetric challenges in proton therapy due to their central location and proximity to critical structures. Proton plans often use ring structures to manage dose falloff, but incorporating a Normal Tissue Objective (NTO) may further improve conformity and OAR sparing while maintaining target coverage. This study evaluates the impact of Eclipse NTO-based optimization on treatment plan quality by comparing dosimetric parameters between plans using only rings (Plan A) and those incorporating both rings and NTO (Plan B).



Results

The integration of a NTO significantly improved dose falloff, reducing dose to surrounding normal tissues.

- Reduced gradient index (GI), IDL volumes (Isodose Line), and mean dose to OARs (p <0.001).
- Conformity index (CI) improved (p <0.001).
- Robustness decreased (p<0.001).
  - All plans met minimum robustness curve requirement.
  - Mean decrease from 99.29% to 98.69%.
  - 6 plans fell below 98% and 2 of those below 97.2%.
- Homogeneity index (HI) increased (p<0.001).



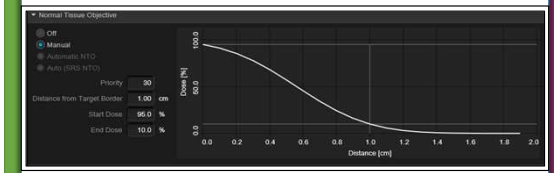
Summary of Results and Direction

Plan A (rings only) minus Plan B (rings+NTO)

	Units	Mean	SD	Min	Max	P-value	Direction
Robustness 95%	cGy	31.4	39.7	-27.7	156.6	< 0.001	↓
Global Max	cGy	-47.4	34.2	-62.6	15.7	< 0.001	↑
CTV Min	cGy	15.5	39.6	-125.3	83.5	0.026	↓
Brain-CTV Mean	cGy	78.2	47.2	19.1	211.7	< 0.001	↓
Cochlea_L Mean	cGy	62.0	82.8	-12.2	265.7	< 0.001	↓
Cochlea_R Mean	cGy	91.6	135.6	-8.2	606.7	< 0.001	↓
Hippocampus_R Max	cGy	539.5	390.8	-83.9	1362.3	< 0.001	↓
Hippocampus_R Mean	cGy	223.8	225.0	-22.3	765.7	< 0.001	↓
Hippocampus_R V7.3	cGy	6.3	8.1	-2.2	39.61	< 0.001	↓
Hippocampus_R D40	%	268.4	334.1	-42.0	1125.9	< 0.001	↓
Hippocampus_L Max	cGy	538.9	474.0	-265.1	1453.9	< 0.001	↓
Hippocampus_L Mean	cGy	198.5	184.7	-11.8	697.9	< 0.001	↓
Hippocampus_L V7.3	cGy	6.6	7.6	-1.3	36.3	< 0.001	↓
Hippocampus_L D40	%	241.6	278.9	0.0	1096.4	< 0.001	↓
Brainstem Max	cGy	-11.3	49.6	-118.8	113.3	0.119	↑
Brainstem Mean	cGy	249.4	194.4	23.9	845.9	< 0.001	↓
Optic Tract Max	cGy	-30.2	39.1	-106.3	28.5	< 0.001	↓
Optic Tract Mean	cGy	171.7	117.6	19.3	568.9	< 0.001	↓
CTV D2	cGy	-24.0	19.8	-79.6	4.9	< 0.001	↑
CTV D98	cGy	5.08	18.6	-32.8	41.5	0.159	↓
95% isodose line	cc	8.0	6.01	1.5	20.0	< 0.001	↓
80% isodose line	cc	14.5	10.0	2.9	39.0	< 0.001	↓
50% isodose line	cc	23.5	14.9	5.3	65.7	< 0.001	↓
30% isodose line	cc	31.1	19.4	7.3	91.2	< 0.001	↓
20% isodose line	cc	62.8	37.8	13.3	177.3	< 0.001	↓
CI	-	0.33	0.18	0.11	0.87	< 0.001	↓
HI	-	-0.56	0.40	-1.20	0.17	< 0.001	↑
GI	-	0.17	0.13	0.00	0.48	< 0.001	↓

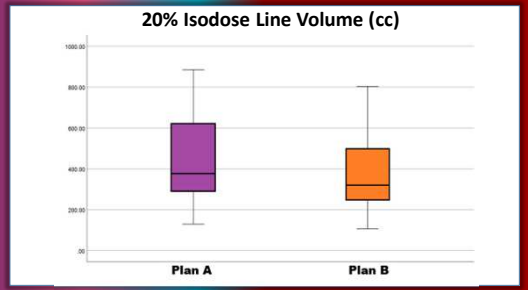
Methods

- 28 retrospective craniopharyngioma cases.
- Plan A (rings only) copied & renamed as Plan B (NTO).
- NTO settings across cases:
  - Variable Priority
  - Distance: 1.00 cm
  - Start %: 95%
  - End %: 10%



- Manual contours and objectives added if not meeting institutional guidelines: required by only 2 cases.
  1. Global hotspot exceeded 108%.
  2. Optic tract dose surpassed 54 Gy.

- **Statistical Analysis:**
  - Normality: Shapiro-Wilk, Kolmogorov-Smirnov, histograms, and Q-Q plots.
  - Tests: Paired t-test & Wilcoxon Signed-Rank test.



Final Thoughts

- NTO is effective because Eclipse SFO optimization hinders sufficient cost on OARs for each beam.
- Potential to improve HI and increasing max doses from study design limitations.
  - This study limited optimizer changes. It's believed these variables could be improved by adding additional objectives to the optimization.
- Future considerations and studies:
  - Application of NTO to other treatment sites.
  - Need to evaluate MFO optimization with NTO.
    - Potential risk for increased modulation with limited control in Eclipse optimizer.
  - A standardized approach to NTO use, may improve reproducibility and streamline clinical implementation.

Conclusion

Adding a NTO to proton therapy plans for craniopharyngioma improved dosimetric outcomes.

- Dose falloff and conformity improved, shown by lower GI and IDL volumes, and CI.
  - **63cc mean reduction in 20% IDL volume.**
- Key OARs—cochleae, hippocampi, optic tract, and brainstem—received reduced doses, suggesting lower toxicity risk.
  - **Average of 5Gy max and 2Gy mean reduction in hippocampal doses.**
  - **2 Gy average reduction of mean brainstem and optic tract doses.**
- Homogeneity index trended higher
- While robustness slightly decreased, values remained clinically acceptable.

These findings support using NTO alongside ring-based optimization to enhance plan quality and warrant further clinical evaluation.