One-Minute Verification and Fully Autonomous VMAT TBI Planning in RayStation for Pediatric Patients

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ABSTRACT

Purpose: To develop and evaluate a fully autonomous VMAT total body irradiation (TBI) planning framework within RayStation that minimizes planner interaction while maintaining consistent plan quality.

Methods: A VMAT TBI planning system was developed using the RayStation Python API. The framework automatically generates planning geometry, beam arrangements, optimization objectives, and supporting structures. User involvement is limited to brief upfront verification before the workflow proceeds unattended.

Results: The system was evaluated on 12 simulated pediatric TBI cases and successfully generated plans for all patients without further user interaction. Mean PTV D90 was 200.3 ± 0.2 cGy, mean PTV D0.03cc was 231.5 ± 1.8 cGy, and average monitor units were 2204.7 ± 126.8 MU. Consistent target coverage, hotspot control, and OAR sparing were achieved across all cases.

Conclusions: The autonomous VMAT TBI framework enables a standardized "verify once, run unattended" workflow that substantially reduces hands-on planning effort while maintaining consistent plan quality. This approach improves planning efficiency, reproducibility, and standardization for complex TBI treatments.

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INTRODUCTION

VMAT Total Body Irradiation (TBI) planning is a complex process requiring multiple isocenters, junction management, and hotspot control to achieve clinically acceptable dose distributions.
Although planning automation has improved efficiency, many workflows still require repeated planner interaction, increasing planning time and variability.

To improve consistency and efficiency, we developed a fully autonomous, RayStation-integrated VMAT TBI planning system that requires only brief upfront verification before completing the entire planning process unattended through a "verify once, run unattended" workflow.

METHODS AND MATERIALS

A fully autonomous VMAT TBI planning system was developed using the RayStation (2024A) Python scripting API. The framework automatically generates planning geometry, treatment beams, optimization objectives, and supporting structures required for pediatric VMAT TBI planning. User interaction is limited to brief verification of automatically generated isocenter placement and beam parameters before the workflow proceeds unattended.
The system performs automated generation of:

- Multi-isocenter geometry
- PTV subdivisions
- Junction structures
- Beam and jaw configurations
- Optimization objectives
- Robustness settings
- Sequential optimization and hotspot control

Following verification, the workflow automatically performs optimization, objective refinement, final dose calculation, and plan saving without further user intervention.

The system was evaluated using 12 simulated pediatric cases derived from craniospinal irradiation datasets extending from head to mid-thigh (ages 4–14 years).

All plans utilized eight VMAT arcs across three isocenters with a prescription of 200 cGy in a single fraction. Dosimetric performance, organ sparing, and planning consistency were assessed across all cases.

RESULTS

The autonomous VMAT TBI planning system successfully generated treatment plans for all 12 pediatric test cases following less than one minute of upfront user verification. Once initiated, the workflow completed isocenter generation, target subdivision, beam creation, optimization, hotspot control, and final dose calculation without further user interaction.

Plan quality was highly consistent across all cases. Target coverage was maintained with a mean PTV D90 of 200.3 ± 0.2 cGy, while hotspots were controlled with a mean PTV D0.03cc of 231.5 ± 1.8 cGy. Mean lung and kidney doses were 112.5 ± 0.5 cGy (56.3 ± 0.2% Rx) and 145.9 ± 0.5 cGy (73.0 ± 0.2% Rx), respectively. Total monitor units averaged 2204.7 ± 126.8 MU.

The workflow demonstrated robust performance across varying patient anatomies and target sizes, producing clinically acceptable dose distributions with minimal variation in target coverage and organ sparing.

The autonomous framework substantially reduced hands-on planning effort while maintaining consistent plan quality and reducing potential inter-planner variability.

Figure 1. Example Case 1
PTV volume: 11527.2 cc
Lung volume: 621.5 cc
Kidney volume: 117.2 cc
Total MU: 2112.8 MU

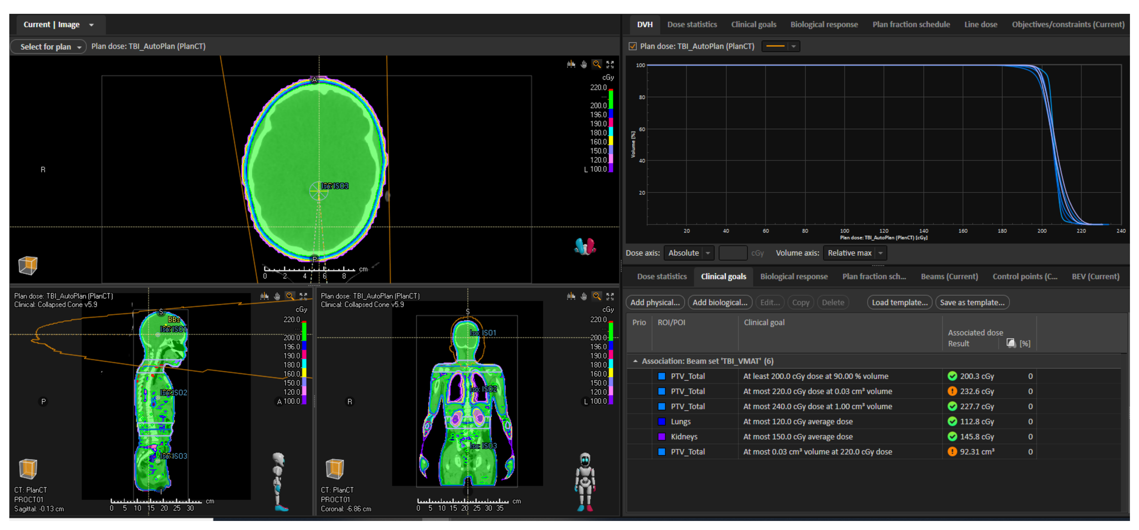

Figure 2. Example Case 2
PTV volume: 15871.3 cc
Lung volume: 1278.2 cc
Kidney volume: 154.0 cc
Total MU: 2185.8 MU

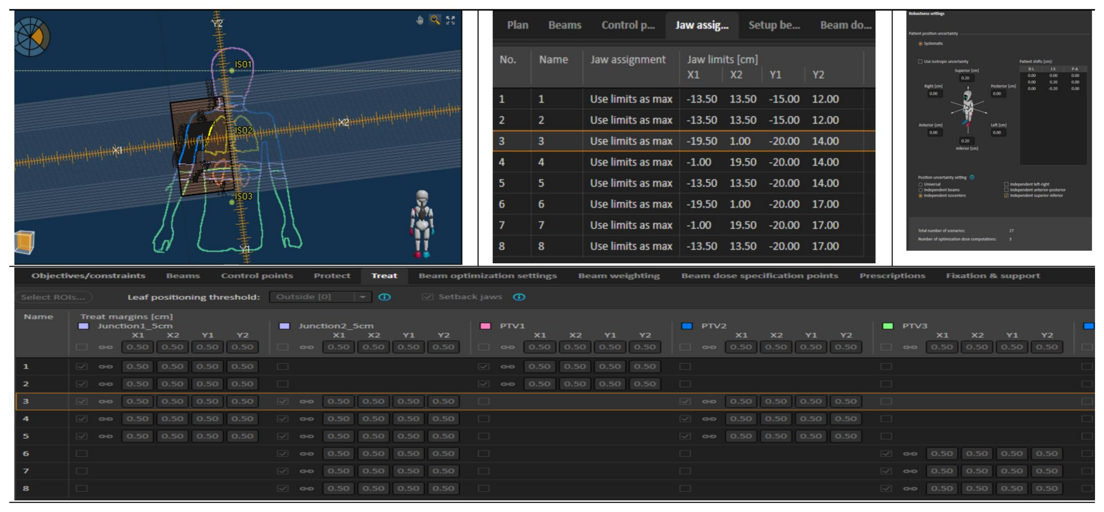

Figure 3. Example autonomously generated VMAT TBI plan demonstrating automatic isocenter placement, target subdivision, and beam generation, requiring only brief upfront human verification (<1 minute from launch).

DISCUSSION

This work demonstrates the feasibility of a fully autonomous VMAT TBI planning framework integrated within RayStation. By limiting user involvement to brief upfront verification and automating all subsequent planning steps, the workflow substantially reduces hands-on planning effort while maintaining consistent plan quality.

The "verify once, run unattended" paradigm improves planning efficiency, standardization, and reproducibility while reducing inter-planner variability. This approach provides a practical pathway toward broader adoption of autonomous treatment planning in radiation oncology.

CONCLUSIONS

A fully autonomous VMAT TBI planning system was developed within RayStation using the Python scripting API. The framework automatically generates planning geometry, treatment beams, optimization objectives, and supporting structures, requiring less than one minute of upfront user verification.

The system demonstrated robust performance across 12 pediatric test cases, consistently achieving target coverage, hotspot control, and organ sparing while completing the planning process without further user interaction.

This framework improves planning efficiency, reduces inter-planner variability, and enables a standardized "verify once, run unattended" approach to VMAT TBI planning.

REFERENCES

Kovalchuk N, Al-Dheiay R, Han B, et al. The Stanford Volumetric Modulated Arc Therapy Total Body Irradiation Technique. *Pract Radiat Oncol.* 2022;12(3):245-258. doi:10.1016/j.prro.2021.12.007