Cureus
Part of SPRINGER NATURE

Open Access
Abstract

Cureus

Automated CyberKnife MLC Planning for Complex Spine Radiosurgery

Youfang Lai [1], Xiaoyu Hu [1], Lawrence R. Kleinberg [2], Kristin J. Redmond [3], Xun Jia [1], An Qin [1]

1. Medical Physics, Johns Hopkins University, Baltimore, USA 2. Radiation Oncology, The Johns Hopkins University School of Medicine, Baltimore, USA 3. Radiation Oncology and Molecular Radiation Sciences, The Johns Hopkins University School of Medicine, Baltimore, USA

Corresponding author: Youfang Lai, ylai44@jh.edu

Categories: Radiation Oncology
Keywords: cyberknife, radiosurgery, spine

How to cite this abstract
Lai Y, Hu X, Kleinberg L R, et al. (March 04, 2026) Automated CyberKnife MLC Planning for Complex Spine Radiosurgery. Cureus 18(3): a1620

Open Access
Abstract
Published 03/04/2026

Abstract

Objectives: CyberKnife radiosurgery offers sub-millimeter precision, but planning is labor-intensive and can take several days, delaying treatment start for time-critical patients and creating a bottleneck for throughput and consistency. Currently, no commercial treatment planning system provides an auto-planning solution for CyberKnife. This study aims to develop and evaluate a novel RayStation scripting workflow that enables automated CyberKnife planning, achieving substantial reductions in planning time while maintaining or improving plan quality for complex spine cases.

Methods: A clinical-goal–driven, CyberKnife planning workflow was implemented in RayStation via scripting. The workflow (i) partitions the PTV into subregions to guide node arrangement for coverage and generates shell rings to control dose fall-off and improve conformity; (ii) translates clinical goals into optimization objectives; (iii) performs iterative optimization by gradually increasing weights for unmet objectives, tightening OAR constraints and refining dose falloff. For each case, multiple candidate plans spanning low to high segment limits and dose modulation were created automatically by the workflow. The best-performing plan in terms of quality and efficiency is selected and finalized with manually fine-tuning as needed. End-to-end planning time, dosimetric metrics (CI, GI, HI, OAR doses), and delivery time were recorded and compared with corresponding plans generated by human planners using Precision planning system.

Results: The workflow was retrospectively tested on 11 spine cases (PTV 46.3–438.1 cm^3). Average planner time was reduced to < 25 mins, compared to 0.5–3 days for manual planning. Script-generated plans achieved improved conformity (CI 1.24 → 1.15; HI 1.75 → 1.69) and comparable OAR maximum doses (cord max dose 2442 cGy → 2518 cGy, esophagus max dose 2553 → 2526 cGy). Dose spillage was reduced, with lower maximum skin dose (2429 cGy → 1990 cGy) and improved dose falloff (GI 4.40 → 3.92). Average delivery time was reduced from 87 minutes to 49 minutes.

Conclusion(s): We successfully delivered a RayStation Scripting-based automated CyberKnife planning framework that tackles the bottleneck of lengthy planning of challenging spine radiosurgery. It reduced planning time by >10-fold with maintained quality, positioning it to streamline workflows, curb planner variability, and standardizing high-quality planning across institutions.