2026 JULY 19–22
VANCOUVER, BC
JOINT AAPM | COMP MEETING

Using Knowledge Based Planning to Shorten Planning Time for Diffuse Midline Glioma

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ABSTRACT

Purpose: Diffuse midline glioma (DMG) is an aggressive central nervous system malignancy typically affecting children and requiring urgent radiotherapy treatment. This study evaluates the application of knowledge-based planning to expedite treatment planning and treatment start, while maintaining plan quality for paediatric patients with brainstem diffuse midline glioma.
Methods: Ten consecutive paediatric patients (ages 3-15) treated over a four-year period were retrospectively analysed. A RapidPlan (RP) model was built using 21 historical cases. Two radiation therapists, one being a paediatric specialist and the other a non-specialist, created conventional VMAT plans and also RP-generated plans for comparison. Planning time, target coverage, conformity index (CI95%), and doses to organs at risk were evaluated.
Results: The average planning time for RP was significantly shorter at 17 minutes (range 9-28) compared to 47 minutes (range 22-71) for conventional VMAT planning, i.e. a reduction of 64%. All plans achieved clinically acceptable coverage, with mean PTV coverage of 98.1% for VMAT versus 97.2% for RP. RP plans demonstrated superior conformity (mean CI95% 1.05 vs 1.24 for VMAT; p=0.00004). No significant differences were found in doses to organs at risk, though a trend toward lower pituitary doses was observed with RP plans (35.4Gy vs 39.4Gy).
Conclusion: Knowledge-based planning using RP significantly reduced treatment planning time for paediatric DMG while maintaining plan quality and improving conformity. This finding was demonstrated for planners with specialist paediatric planning expertise and also for those with less paediatric experience. RapidPlan enables efficient high-quality VMAT planning, supporting same-day plan-and-treat workflows that are essential for DMG cases requiring emergency treatment.

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INTRODUCTION

Diffuse midline glioma (DMG), alternatively termed diffuse intrinsic pontine glioma (DIPG) is a rare but highly aggressive central nervous system (CNS) malignancy occurring primarily in children and young adults. Located in midline brain structures, mostly in the brainstem, but may also occur in other midline structures such as the thalamus and spine. Survival and prognosis have shown little improvement. Radiation therapy remains the main treatment, where the goal is to slow tumour progression, relieve symptoms, and maximize tumour control. Median OS and PFS after radiation therapy (+/- systemic therapy) is 11.4 months and 7.7 months (1).

The median age of DMG diagnosis is 6 -7 years (2) and patients present with widely varying and rapidly progressing neurological symptoms. These frequently necessitate urgent radiotherapy, which has traditionally limited initial treatment to simpler techniques while transitioning to more conformal plans when ready. However such field-based techniques, using anatomic landmarks may inadequately cover the tumour or provide insufficient margins for clinical spread.

Knowledge-based planning (KBP) can improve plan efficiency and quality (3). This is evaluated here, using a RapidPlan model developed specifically for DMG, aiming to expedite treatment planning, while maintaining plan quality, including minimising critical organ doses.

METHODS AND MATERIALS

Ten consecutive paediatric patients (ages 3-15) treated over 2020-2023 were retrospectively analysed. Original treatment target volume and organ at risk contours were used for VMAT re-planning, to 54Gy in 30 fractions. A RapidPlan (RP) model was built (using the RP module in Eclipse v16.1.2 and photon optimiser algorithm v16.1.2) using 21 historical cases, (2013-2021), all VMAT re-planned. Model performance was assessed by comparing the clinical VMAT plans with those from the RP model.

Two radiation therapists—one paediatric specialist and one non-specialist—created conventional VMAT and RP-generated plans for the ten cases. VMAT planning time was assessed using a standard paediatric VMAT brain protocol applied under 'urgent treatment' conditions. To simulate urgent clinical conditions for the RP cases, they were limited to a maximum of two optimization cycles to refine the initial plan generated by RP.

All plans were evaluated by a paediatric radiation oncologist for quality and clinical safety. Further analysis focused on comparative dosimetric and timing evaluation. Planning time, target coverage, DVHs, conformity index (CI95%), and doses to organs at risk were considered.

RESULTS

Mean planning time:
For VMAT: 47 min (range 22-71)
For RP plan: 17 min (range 9-28)
Median 15 and 51, respectively.
RP plan significantly shorter, around 1/3.

Both RTs showed similar times for completing VMAT plans and also both had similar times for completing RP plans.

All plans achieved planning objectives and were clinically acceptable (Tables 1 and 2):
- mean PTV coverage 98.1% for VMAT , 97.2% for RP
- RP plans: superior conformity (mean CI95% 1.05 vs 1.24 for VMAT; p=0.00004) (Fig 1).

- OAR doses: no significant differences (Table 2)
- trend toward lower pituitary doses with RP plans (35.4Gy vs 39.4 Gy)

Table 1. PTV volume receiving 95% of Dose. CI = conformity index

	VMAT	RP	p
Mean	98.1%	97.2%	
SD	1.7	2.2	
Min	93.9	94.0	
Max	100	100	
PTV CI95% mean	1.24	1.05	0.00004

Table 2. Organs at risk doses

OAR	VMAT mean (Gy)	RP mean (Gy)
Cochlear left mean	29.3	**30.1**
Cochlear right mean	30.6	**29.9**
Optic chiasm max	48.6	**48.4**
Pituitary mean	39.4	**35.4**
Spinal cord max	43.5	42.6

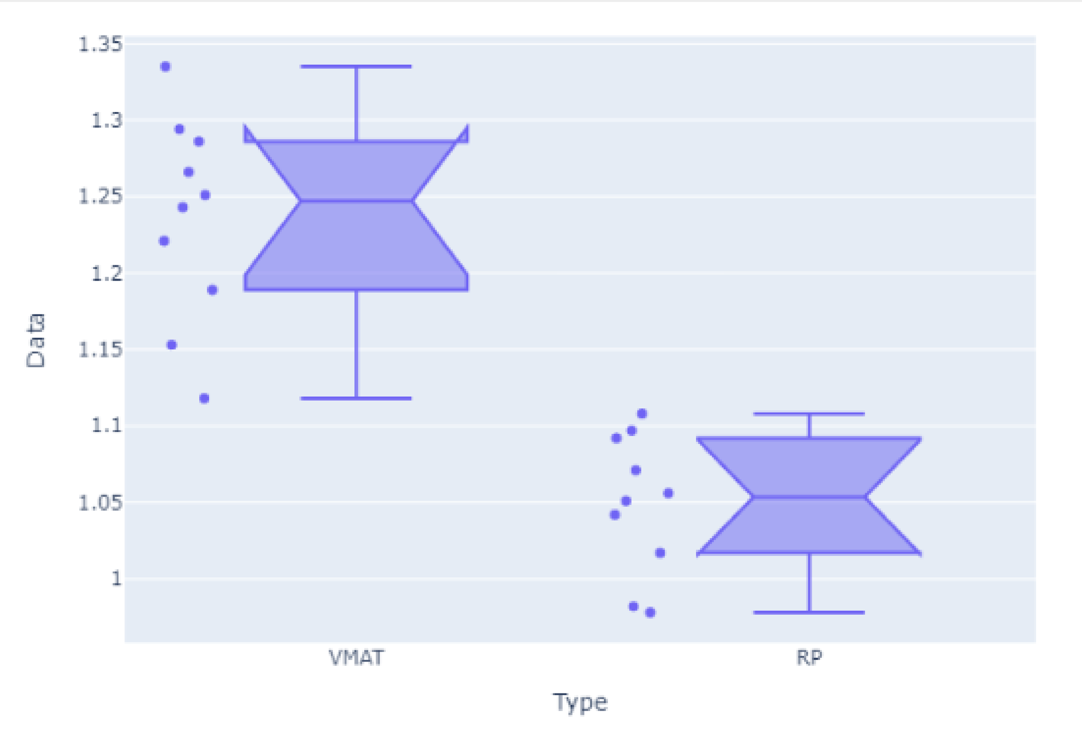

Fig 1. PTV CI95% for VMAT and RP plans. Box plots illustrate the distribution of CI95% across the two approaches, showing variability and mean differences between VMAT and RP plans.

DISCUSSION

The mean RP planning time was significantly lower than that for VMAT. This is particularly significant in a clinical context where time is critical, where delays in radiotherapy can lead to disease progression and worsened symptoms. Streamlining planning without compromising quality can improve patient outcomes and optimize resource allocation. The RP approach allows for non-specialist radiation therapists to produce high-quality plans in a shorter time for these paediatric patients, which is important as an experienced paediatric radiation therapist may not be available when emergencies present.

An RP model can be readily adapted to other dose fractionation, such as hypofractionation (4), or for re-irradiation. However, challenges persist in developing comprehensive models, particularly for paediatric cancers with limited patient populations. Despite potential limitations (e.g. retrospective design and sample size), the model developed showed robust performance compared to standard VMAT planning, with potential for further refinement through additional case inclusion.

This study has provided the first published validated RP model for DMG. It has shown RP plans decrease planning time, whilst also maintaining plan quality, including improved PTV conformality, suggesting that the RP model may better spare surrounding healthy tissues, particularly important for a paediatric population.

CONCLUSIONS

Knowledge-based planning using RapidPlan significantly reduced treatment planning time for paediatric DMG while maintaining plan quality and consistency and improving conformity. This was shown for planners with paediatric planning expertise and also those with limited experience.

Implementation of KBP can improve efficiency and reduce treatment delays for paediatric patients with diffuse midline glioma, who often present as an emergency and require urgent treatment.

KBP models can be developed even for rare cancers and are feasible within real-world clinical workflows, including urgent or time-sensitive scenarios.

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