Impact of MC Dose Algorithm for CNS Proton Treatments

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INTRODUCTION

In 2017, IROC published a paper titled "Pencil Beam Algorithms Are Unsuitable for Proton Dose Calculations in Lung"[1]. The wide availability of commercial TPS MC algorithms and adequate computing power raises consideration of employing the more accurate algorithm for other sites as well. While the goal in lung is to ensure target coverage, the impact on more homogeneous tissue sites (e.g. brain) is to increase the magnitude of the dose without changing the shape of the dose distribution. This raises a concern in CNS where early clinical data suggest modest risk of radiation and symptomatic necrosis[2]. Additionally, there are efforts to determine better (variable) RBE models to replace the standard uniform value of 1.1. However, that value is based on historical treatments (using a pencil beam algorithm). Having accurate physical dose estimates is one requisite to more accurately determine RBE.

AIM

The aim of this work is to evaluate systematic dose differences between the pencil beam and the MC dose algorithms in Raystation 9 for CNS proton therapy treatment plans.

While the MC algorithm is more accurate, most clinical experience for CNS has been with a pencil beam algorithm. Historically prescriptions and the uniform RBE value (1.1) are based on clinical experience and may not be valid when using a MC dose algorithm.

METHOD

- An IRB-approved retrospective study was conducted on 30 CNS patient treatment plans.
- Patients were treated using an IBA pencil beam with range shifters either 4 or 7.5 cm water equivalent thickness (WET).
- Previously delivered treatment plans were anonymized and copied to a research database.
- The plans were re-calculated with the latest beam models in the current planning system (Raystation 9a) using the pencil beam algorithm (PBA).
- These plans were then copied and re-calculated using the latest Monte Carlo (MC) algorithm in the same planning system.
- A dosimetric comparison between the two planning algorithms was done on a patient-by-patient basis.
- The dose covering 99, 98, 95, 50, 2 and 1% of the GTV, CTV and PTV was evaluated as well as the average dose to each of those structures.

RESULTS

Fig. 1: Example of a peripheral lesion planned with PBA (top left) and then recalculated with MC (bottom left). DVH (top right) shows that the MC calculation indicates the tumor is uniformly underdosed. Difference map (bottom right) shows the underdosed region (warm colors) as well as where the excess protons go.

Peripheral lesions are treated with the thickest range shifter (7.5cm WET). The scatter and air-gap from the range shifter are only approximated by the pencil beam algorithm resulting in a delivered dose 1.5 to 4% less than planned, according to the MC calculations. Correspondingly, had the plans been optimized initially with the MC dose algorithm patients would have received 1.5 to 4% more dose.

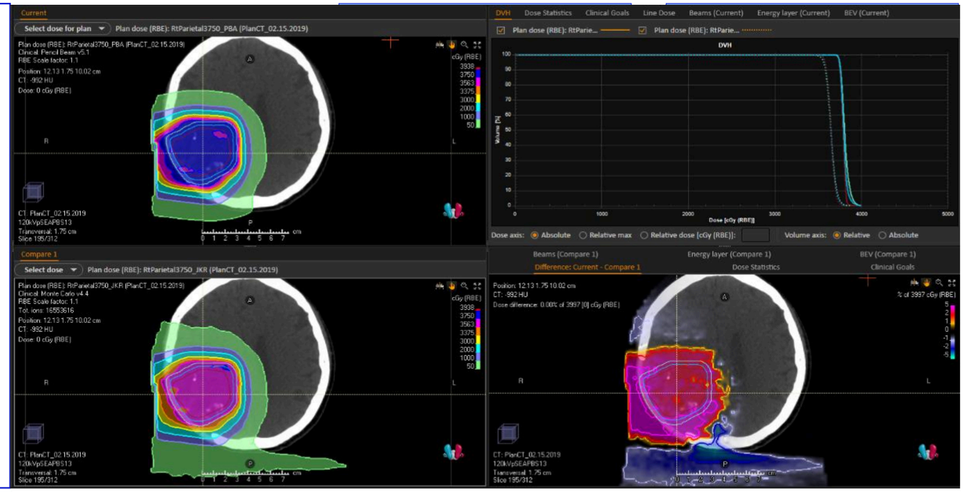
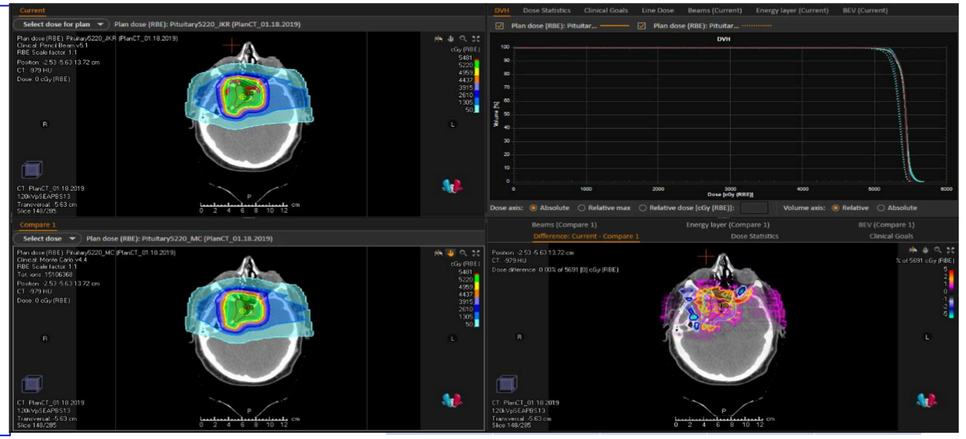


Fig. 2: Example of a deeper/central lesion. This plan used a 4cm WET range shifter while Fig. 1 was with a 7cm WET range shifter.

The overall dose difference is significantly less for this case. There is also more variation in the dose difference due to anatomical tissue heterogeneities (bone, air).



CONCLUSIONS

A systematic dose difference was seen for all cases. The trend was independent of target (GTV, CTV or PTV), and coverage level (1% to 99%). Average dose to the CTV had the most consistent ratio, with MC calculations being 1.5 to 4% lower than PBA. Dose differences were independent of tumor size which ranged from GTV's of less than 5cc to greater than 90cc. Peripheral tumors (reaching the skull) showed an average dose difference of 2.5% while centrally located tumors had an average dose difference of 1.5%.

The accuracy of PBA dose calculations is affected by the in-room range shifter. Thicker range shifters (for peripheral tumors) create a larger effect than thinner ones for deeper tumors. Even for relatively homogeneous CNS targets switching from PBA to MC for plan optimization will result in systematically higher doses than what most clinical experience is based on. Based on our data, historical doses (in CNS) may be 2-4% lower than reported. One could suggest changing to a uniform RBE of 1.13 for MC treatment plans to better match historical treatments.

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REFERENCES

1. Taylor et al. IJROBP 99(3), Nov. 2017, pp 750-6.
2. Aljabab et al. Neurosurgery-Online 84(5), May 2019, pp E362-3.

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