Use of VirtuaLinac to perform Monte-Carlo based dose calculation for verification of radiotherapy treatments on a jawless gantry linac with double stack MLC

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JULY 12–16 2020 VIRTUAL JOINT AAPM | COMP MEETING EASTERN TIME [GMT-4]

INTRODUCTION

- VirtuaLinac (VL) platform developed by Varian Medical Systems® is a Monte-Carlo calculation package capable of simulating interactions in a linac treatment head and the dose deposition in a virtual phantom or CT dataset.[1,2] VL runs on Amazon Web Services (AWS) cloud network providing enhanced computation power.[3]
- Halcyon, a ring gantry linac, has a compact design with a jawless treatment head and double stack multi-leaf collimator (MLC) system.[4]
- A head shielding model for the TrueBeam® Radiotherapy system was developed for VL and validated by comparing MC simulations with TB measurements.[2] However, to our knowledge, there is no MC simulation and modeling reported with the Halcyon linac.

AIM

We aim to demonstrate VL's ability to perform MC-dose calculation to verify plan fidelity from a newly released ring gantry linac, Halcyon, with double stack MLC and 6MV FFF beam.

METHOD

- A workflow was established using VL via AWS with plan, structure, and CT dataset as input and VL calculated MC dose as output. Multiple Halcyon plans were generated using Eclipse TPS for comparison.
- Validation cases included static fields on a virtual water phantom and Task Group 119 (TG-119) plans with dynamic MLC on a solid water phantom.
- For each plan, XML files with MLC positions, gantry angle, and collimator were used as input to the VL.
- 1D beam profiles, dose differences, and 3D gamma passing rate (3%/3mm) were used as evaluation metrics to assess plan fidelity.
- The test experiments were conducted on a 30 x 30 x 30 cm^3 water phantom. Because there is a difference in dose grid resolution between TPS (2.5 mm) and VL (4 mm), VL output was up-sampled to match the TPS-derived dose grid (Figure 1).
- For the TG119 phantom, the planning CT images were acquired at 0.97 x 0.97 x 2.5 mm^3 resolution and resampled to dose grid resolution (1 x 1 x 0.83 mm^3 resolution) prior to VL input (Figure 1).

RESULTS

- Both open field and TG119 cases were successfully simulated. For all cases, the 1D profiles in both directions matched well (Table 1).
- For open field calculation on water phantom, 3D Gamma was 94.3%, 98.2%, 99.2% for a 4x4, 10x10, and 28x28 cm^2 field size, respectively.
- Simulations with an AP/PA, AP3S (dynamic MLC with 3 segments), and four-field box resulted in a Gamma of 93.6%, 97.6%, 93.9%.
- A 9-beam Head-Neck IMRT plan generated a 95.0% Gamma.
- Simulations on the TG119 phantom included AP beam (93.0%), AP/PA (93.0%), and AP3S (92.3%).
- Percent depth dose (PDD) and beam profiles at a given distance from the surface for TPS and VL-derived plans are plotted.

Table 1

Plan	Phantom	#particles	Gamma (%)
4x4 AP	Water	1.0e8	94.3
10x10 AP	Water	1.0e8	98.2
28x28 AP	Water	1.0e8	99.2
10x10 AP/PA	Water	2.0e7	93.6
10x10 AP3S	Water	2.0e7	97.6
10x10 4-field	Water	4.0e7	93.9
HN IMRT	Water	9.9e7	95.0
10x10 AP	TG-119	3.0e7	93.0
10x10 AP3S	TG-119	1.0e7	92.3
10x10 AP/PA	TG-119	2.0e7	93.0

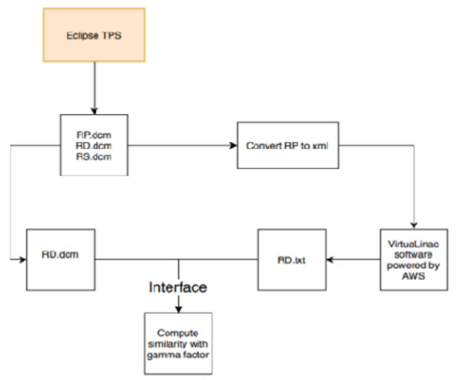

Figure 1: Dose comparison workflow for water phantom. Similar algorithm is in place for workflow on the TG119 phantom.

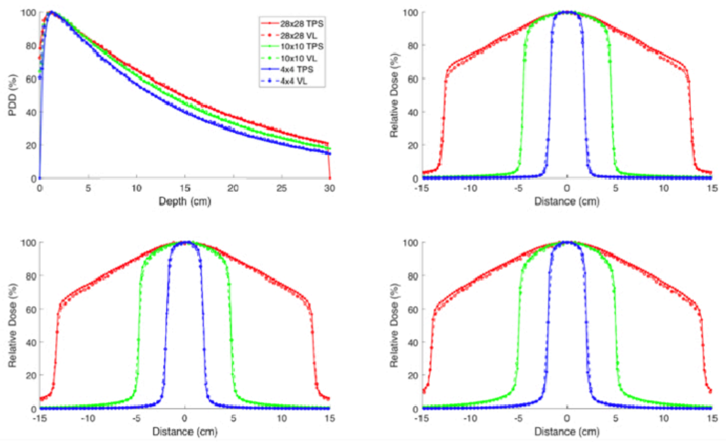

Figure 2: PDD (top left) and Beam Profiles at 1.3 cm (top right), 5 cm (bottom left), and 10 cm (bottom right) for Anterior-Posterior (AP) beams of size 4x4 cm^2, 10x10 cm^2, 28x28 cm^2 plans on a water phantom.

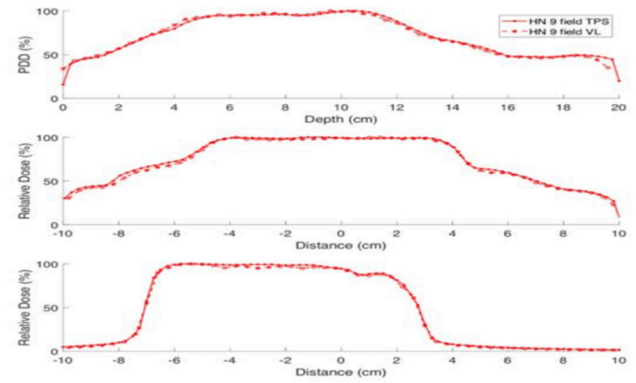

Figure 3: PDD & Beam Profiles at 1.3 cm (middle) and 10 cm (bottom) from surface for 9-field HN IMRT on a water phantom.

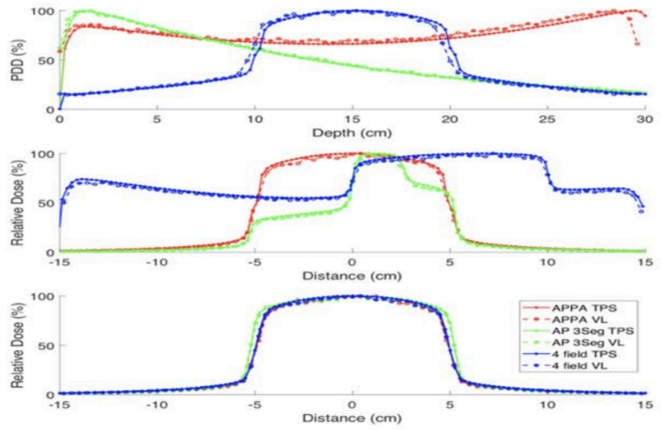

Figure 4: PDD (top left) and Beam Profiles at 1.3 cm (middle) and 10 cm (bottom) from the surface for AP/PA, AP3S, and four-field (orthogonal beam) plans on a water phantom.

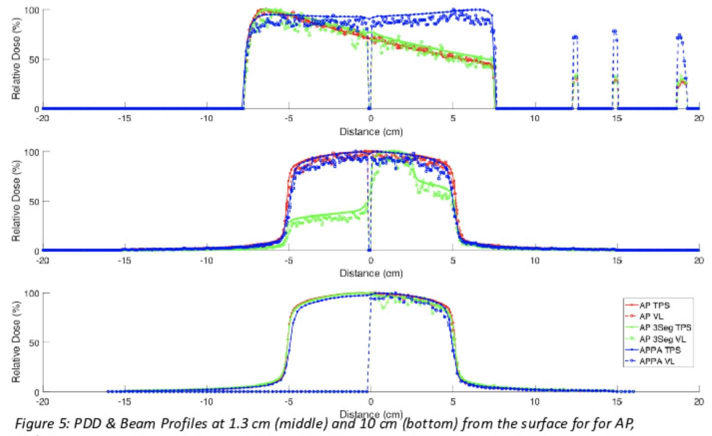

Figure 5: PDD & Beam Profiles at 1.3 cm (middle) and 10 cm (bottom) from the surface for for AP, AP/PA, AP3S on a TG119 phantom.

CONCLUSIONS

- The VL represents the first MC simulation and modeling for the Halcyon linac and is a promising tool for TPS dose calculation on both the water and TG-119 phantom.
- Our study provides an innovative technique and proposed workflow for the comparison of Eclipse TPS dose calculation with a Monte Carlo-based simulation of the treatment head and dose deposition for the Halcyon linac.
- This tool will be valuable for translation into the clinic, most noticeably with patients undergoing adaptive radiotherapy.
- Future work will optimize simulation resources and plan accuracy aimed to translate VL into clinical workflow including comparison tests on patient plans.

ACKNOWLEDGEMENTS

I would like to thank the Radiation Oncology Team at Washington University for their continuous support and dedication towards the project. I would also like to thank Varian Medical Systems for their support and funding for this project.

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