Comprehensive Open-Field Dosimetric Validation of Commercially Available Monte Carlo Secondary Dose verification System for Photon Radiotherapy

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PURPOSE / OBJECTIVES

To perform comprehensive dosimetric validation of a commercially available independent Monte Carlo (MC)-based secondary dose calculation engine for clinical photon radiotherapy.

MATERIAL & METHODS

A suite of open-field dosimetry measurements for 6MV and 10MV flattened and flattening filter free (FFF) photon energies were acquired on a C-arm linear accelerator for validation against MC simulations. A 0.07cc scanning ion chamber was used to measure dose profiles in a homogeneous water phantom, including transverse and radial beam profiles at varying depths (dmax to 30 cm) and percent depth doses (PDDs) spanning clinically useful square-field sizes (ranging from 3x3 to 40x40cm). Analogous three-dimensional (3D) MC simulations were performed with a commercially available secondary dose calculation engine (RadMonteCarlo, Radformation, NY). The number of MC histories per measurement condition was field-size dependent and increased such that the mean statistical uncertainty was less than 0.3%.

For a given measured profile, associated MC data were extracted from the simulated 3D dose volumes, which were averaged across all histories. This data was convolved with a Gaussian kernel with a 5 mm FWHM to account for detector volume averaging in measured data. MPPG5a dose difference (DD) and distance-to-agreement (DTA) evaluation criteria were employed to compare measured data against MC simulations.

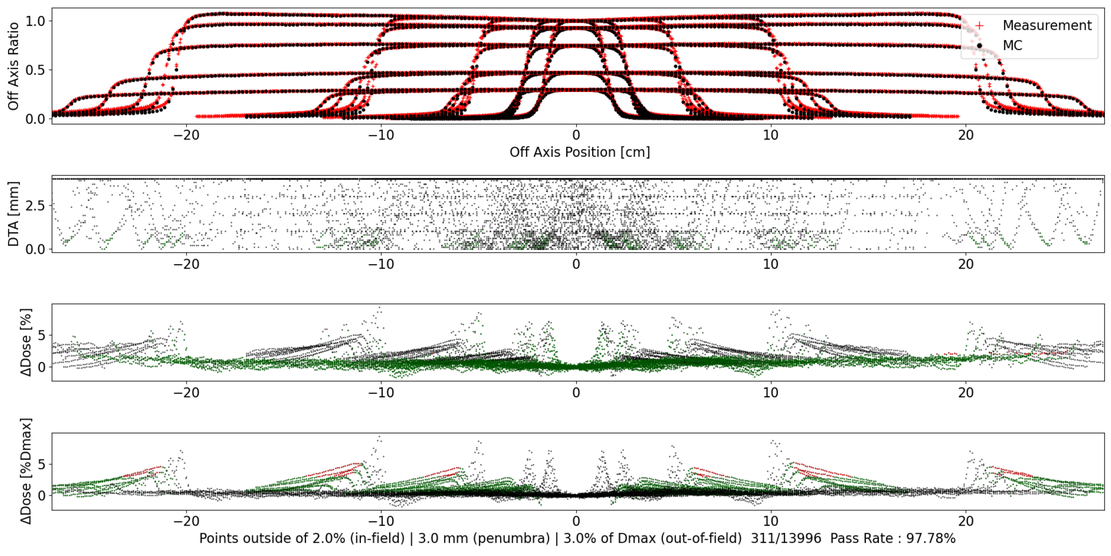

Figure 1: *: In-plane profiles across all field sizes for 10 MV, with raw measurement and MC data, DTA analysis, DD analysis, and composite DTA/DD analysis plotted (top to bottom respectively). Of note, a majority of the failing point are in the low-dose, out-of-field region which may highlight current limitations in the statistical uncertainty of the MC data.*

RESULTS

All measured PDD data points (n=12000) agreed with MC simulations across all energies and field sizes at 2% or 2mm DD/DTA criteria. For cross-plane profiles, all measured points (n=27,964) for 6FFF and 10FFF energies agreed with MC simulations evaluated at 2% DD in-field, 3mm DTA in penumbra, and 3% of maximum field dose out-of-field. Minimal disagreement was observed for 6MV (n=40/13976) and 10MV (n=311/13996) profiles, primarily in the out-of-field regions for large field sizes.

Innovation/Impact: The dosimetric validation of a commercially available Monte Carlo (MC)-based secondary dose calculation system against clinically commissioned measured photon data would show the feasibility of using such a tool in benchmarking commissioning data for other machines and centers. This could help improve beam modeling robustness and reduce dosimetric variations across centers and machines.

Key Results: Table 1 shows results aggregated across field sizes when comparing measured beam data against associated MC simulation data for a given photon beam energy in terms of PDDs (a) and in-plane profiles (b). Figure 1 helps visualize these evaluations for a representative set of data with non-zero failing points using MPPG 5a evaluation criteria. Of note, flattened 6 MV and 10 MV contained a small number of failure points mostly in the out-of-field or tail region of the in-plane profiles. While minimal, these points of disagreement warrant further investigation into the integrity of both the MC simulations and measurement data and is an area of ongoing work.

	PDDs			In-plane Profiles		
Energy	Number of Disagreements	Number of Points Evaluated	Passing Rate (%)	Number of Disagreements	Number of Points Evaluated	Passing Rate (%)
6FFF	0	3000	100.00	0	13968	100.00
6MV	0	3000	100.00	40	13976	99.71
10FFF	0	3000	100.00	0	13996	100.00
10MV	0	3000	100.00	311	13996	97.78
Total	0	12000	100.00	351	55936	99.37

Table 1: Aggregate evaluation results comparing measured data against MC simulations utilizing MPPG 5a criteria of 2% DD in-field, 3mm DTA in buildup/penumbra (PDD/profile), and 3% of maximum field dose out-of-field.

SUMMARY / CONCLUSION

This study provides a comprehensive dosimetric validation of a commercial MC-based secondary dose calculation engine and demonstrates its clinical utility for benchmarking measured data.

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