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Validation of Commercial Monte Carlo Secondary Dose Calculation Using External Audit End-to-End Phantoms

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PURPOSE / OBJECTIVES

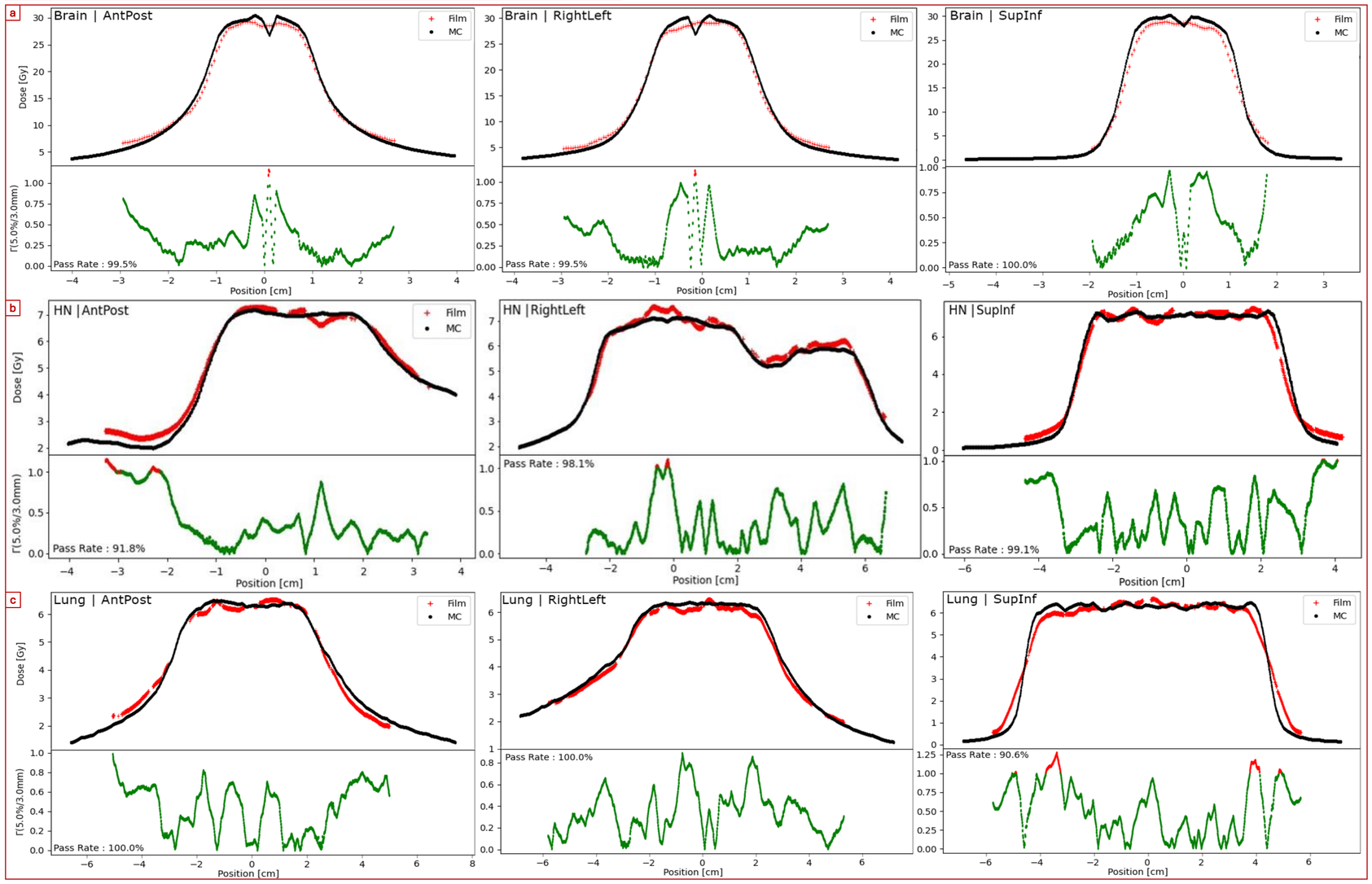
This work provides a verification of a commercially available Monte Carlo secondary dose calculation engine against end-to-end IROC phantom measurements across multiple disease sites and delivery platforms. IROC independent audits provide an external, standardized benchmark, helping identify dosimetric or workflow issues that may not be apparent from internal QA alone. By demonstrating consistency with established IROC gamma and TLD acceptance criteria, these results offer early validation of the algorithm's clinical reliability and support its use for independent dose verification and institutional quality assurance. This study establishes a foundation for broader adoption of Monte Carlo–based secondary dose calculation tools in clinical practice.

MATERIAL & METHODS

Twelve anthropomorphic IROC phantoms were evaluated. Each phantom was irradiated on a linear accelerator. IROC reports provided film-measured dose profiles along the anterior–posterior, right–left, and superior–inferior axes, as well as TLD measurements for target and OARs locations. The corresponding treatment plans were independently recalculated using the commercial RadMonteCarlo secondary dose calculation engine (Radformation, NY). Dose profiles were sampled through the phantom center using phantom orientations and matched to the IROC film profiles. An in-house tool was used to digitize the IROC plots, align the profiles, and perform one-dimensional gamma analysis. Comparisons were conducted using the standard IROC 7%/5mm criterion, 5%/3mm for all cases, 7%/4mm for head and neck cases, and 5%/1mm for brain radiosurgery cases. TLD dose differences were evaluated using the IROC ±7% acceptance tolerance.

Phantom	Site	7%/5 mm Pass (%)	5%/3 mm Pass (%)	Phantom-Specific Pass (%)
Brain	Site 2	100	99	93.7 (5%/1mm)
Brain	Site 1	99.5	90.7	90.2 (5%/1mm)
Brain	Site 5	100	91.1	88.3 (5%/1mm)
HN	Site 1	99.6	95.8	99.6 (7%/4mm)
HN	Site 5	100	96.7	100 (7%/4mm)
HN	Site 6	97.6	89.5	95.9 (7%/4mm)
Lung	Site 1	100	91.6	100(5%/5mm)
Lung	Site 2	100	96.4	98.6(5%/5mm)
Lung	Site 3	100	98	100(5%/5mm)
Lung	Site 2	99.9	97.4	98(5%/5mm)
Lung	Site 6	100	95.1	95.7(5%/5mm)
Lung	Site 2	100	98.3	100(5%/5mm)

Table 1: Gamma pass rate agreement between IROC-reported dose profiles and independently extracted treatment planning system (TPS) dose profiles for clinically delivered IROC phantom cases. Results are shown for the standard IROC credentialing criteria (7%/5 mm), a uniformly tighter criterion applied across all sites (5%/3 mm), and literature-supported site-specific criteria (5%/1 mm for brain phantoms and 7%/4 mm for head and neck phantoms). Dose profiles were compared along the superior–inferior, right–left, and anterior–posterior axes after centering and alignment. Lung phantom cases were evaluated using only the standard and uniform tighter criteria.



RESULTS

MC–calculated dose profiles demonstrated close agreement with IROC-reported results across all phantom types under the standard 7%/5mm criteria (Table 1). Application of tighter 5%/3mm criteria revealed increased sensitivity, particularly for brain phantoms, where steep dose gradients and small field sizes resulted in lower pass rates for select cases. These trends are consistent with the increased stringency of tighter criteria and did not impact IROC credentialing outcomes. TLD analysis showed MC–calculated doses agreed with IROC measurements within the 7% tolerance across all phantom types, consistent with the profile-based gamma results (Figure 1).

FIGURES

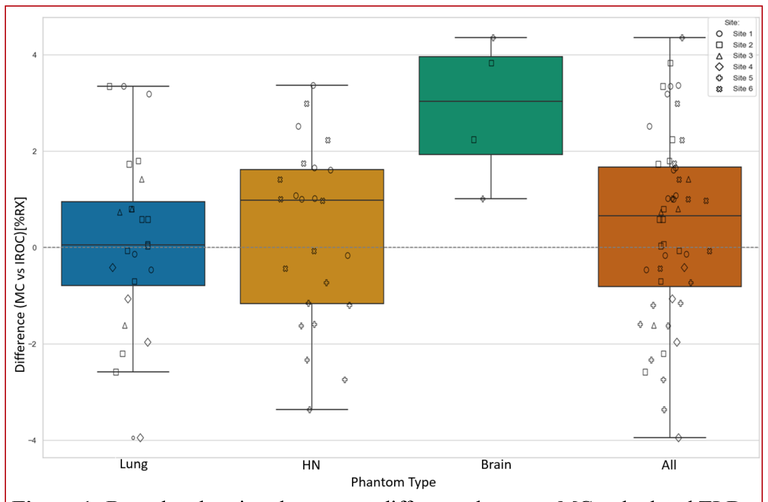


Figure 1: Box plot showing the percent difference between MC-calculated TLD dose values and IROC-reported measurements. Results are grouped by phantom type (lung, HN, and brain), with additional group showing all cases combined. The horizontal dashed line indicates zero difference between MC and IROC results. Lung and HN cases showed differences within 3%. Brain cases exhibited larger variability, with differences ranging from 1.1% to 4.4%. Across all sites and phantom types, differences were within 4.4%.

Figure 2: Representative gamma analysis for IROC phantom cases evaluated using the 5%/3 mm criterion: (a) brain, (b) head and neck, and (c) lung. For each case, dose profiles extracted from the IROC report are compared with Monte Carlo–calculated TPS dose profiles along the anterior–posterior (AntPost), right–left (RightLeft), and superior–inferior (SupInf) axes, with corresponding gamma values plotted as a function of position. Axis-specific gamma pass rates were 99.5% (AntPost), 99.5% (RightLeft), and 100% (SupInf) for the brain case; 91.8%, 98.1%, and 99.1% for the head and neck case; and 100%, 100%, and 90.6% for the lung case, respectively. Overall gamma pass rates were 98.1%, 96.7%, and 96.7% for the brain, head and neck, and lung cases, respectively. Corresponding coronal and sagittal pass rates were 97.4% and 98.3% for brain, 98.5% and 95.9% for head and neck, and 95.2% and 95.0% for lung.

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SUMMARY / CONCLUSION

RadMonteCarlo dose calculations showed strong agreement with IROC film and TLD measurements across all anatomical sites irradiated, brain, head and neck, and lung phantoms on multiple linear accelerators. All cases met the standard IROC 7%/5 mm gamma criteria, and all TLD differences remained within the ±7% IROC tolerance. Tighter gamma criteria maintained generally high agreement but revealed increased sensitivity in brain cases, where small fields and steep dose gradients produced lower pass rates. These findings demonstrated that existing institutional IROC credentialing data can be repurposed as an independent benchmark for validating new dose calculation tools. Using this approach, RadMC was successfully validated against end-to-end external audit measurements, supporting its use for secondary dose verification and institutional quality assurance.

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