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Clinical Implementation of Log File Analysis for Patient-Specific QA

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ABSTRACT

To clinically validate log file–based patient-specific QA (LFA) for IMRT/VMAT as an efficient alternative to measurement-based QA while maintaining compliance with AAPM TG-218.

Radformation LFA v2.5 with RadMonteCarlo (Eclipse v16.12) was evaluated across 22 IMRT/VMAT plans on Varian TrueBeam linacs. Trajectory logs (MLC, gantry, dose rate) were used to reconstruct delivered dose on patient CT. Gamma analysis followed TG-218 (2 mm/3% at 3 mm voxels) with escalation to 1.5 mm and/or up to 5%.

Strong agreement was observed between planned and delivered dose. Eleven cases achieved >95% (full dose matrix) and >90% (high-dose PTV) using standard criteria. Lower initial pass rates were associated with heterogeneous and buildup regions.

LFA provides a robust, efficient, and clinically viable PSQA approach when supported by TG-142 machine QA and structured departmental criteria.

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INTRODUCTION

Intensity-modulated radiation therapy (IMRT) and volumetric modulated arc therapy (VMAT) require robust patient-specific quality assurance (PSQA) due to their delivery complexity. Traditional measurement-based QA methods are reliable but require significant physicist time and linac downtime. Modern linear accelerators generate trajectory log files that record delivered machine parameters, including multileaf collimator positions, gantry motion, and dose rate, for every treatment fraction. When combined with Monte Carlo dose reconstruction, log file analysis (LFA) enables dose recalculation directly on the patient CT dataset, providing an efficient and truly patient-specific QA approach. The purpose of this work was to clinically validate LFA as a scalable alternative to conventional measurement-based QA for IMRT and VMAT treatments while maintaining compliance with AAPM recommendations.

METHODS AND MATERIALS

22 IMRT/VMAT plans generated in Eclipse v16.12
Plans delivered on two Varian TrueBeam v3.0
Radformation LFA v2.5 with RadMonteCarlo
Trajectory logs (MLC positions, gantry motion, dose rate)
Dose reconstructed on patient CT using Monte Carlo
Gamma analysis (TG-218 aligned): 2 mm / 3% at 3 mm voxels Escalation: 1.5 mm voxels and/or up to 5% dose difference
Metrics: Whole-dose matrix High-dose PTV

CLINICAL WORKFLOW

1. **Deliver plan on TrueBeam**
   Trajectory logs automatically captured
2. **Automatic log file import**
   Delivered MLC/gantry/dose-rate extracted
3. **RadMonteCarlo 3D dose reconstruction**
   Monte Carlo recalculation on patient CT
4. **Metrics Assessed**
   Whole dose + high-dose PTV with TG-218 aligned criteria
5. **Escalate if needed**
   1.5 mm voxels and/or relaxed dose difference up to 5%
6. **Pass / investigate / measurement-based follow-up**

RESULTS

LFA demonstrated reasonable agreement between planned and delivered dose. Eleven cases achieved >95% gamma passing for the full dose matrix and >90% for high-dose PTVs using standard criteria. Cases involving air–tissue interfaces, heterogeneous anatomy, buildup regions, or implanted hardware demonstrated lower initial pass rates, consistent with known algorithmic differences between AAA and Monte Carlo dose calculations.
The lowest result, 93.03% for the high dose PTV, was for the target of a head and neck treatment site, which was near an airway and near the surface at the buildup region, requiring the alternate gamma criteria.
Comparable trends were observed between LFA and conventional measurement-based QA for complex cases as shown in Figure 1 below.

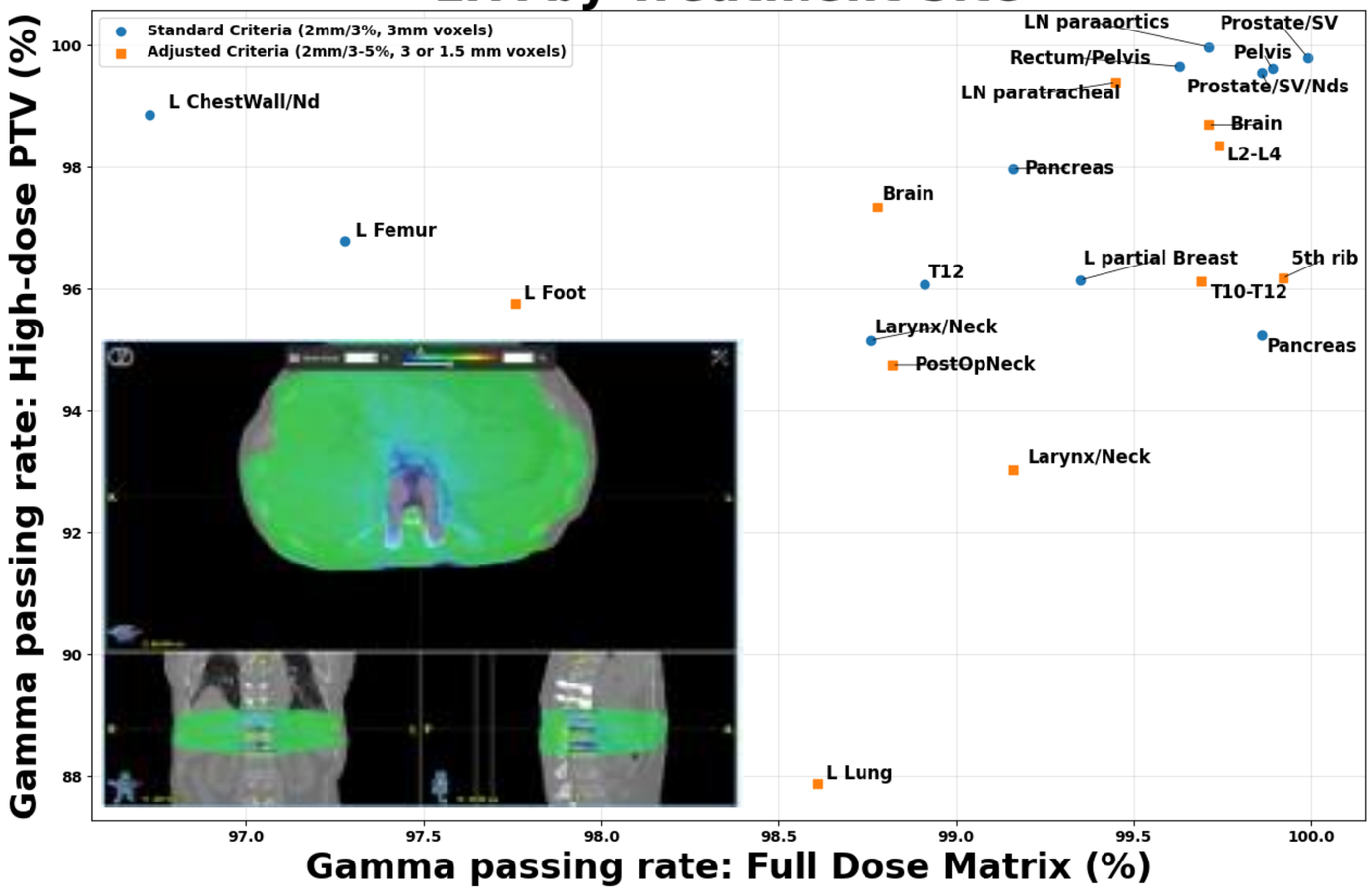

Figure 1: Distribution plot of composite results. Cases requiring adjusted gamma criteria denoted by orange squares. Left inset image of 3D RadMonteCarlo gamma analysis with dose color wash. Areas of low agreement in the vertebral hardware are in blue tone.

DISCUSSION

LFA reconstructs the delivered dose directly on the CT dataset, enabling highly accurate modeling of heterogeneities such as lung, air cavities, bone, and implanted hardware. A full Monte Carlo simulation is created using the delivered machine parameters from delivery log files.This produces a gold-standard 3D dose matrix and detailed gamma analysis for targets and organs at risk, providing high-fidelity evaluation.
In addition to volumetric 3D statistics for target and normal structures, these comparisons visualize differences between planned and log-based recalculated fluence maps, improving the interpretability in regions of buildup and loss of lateral electronic equilibrium. LFA workflow reduces the need for phantom setup and physicist labor, thereby improving efficiency without compromising plan validation.

CONCLUSIONS

When supported by clearly defined acceptance criteria and continued machine QA, LFA enables streamlined workflows while preserving dosimetric rigor, particularly when used with informed clinical judgment. In conclusion, LFA provides a robust, efficient, and clinically viable approach for PSQA.

REFERENCES

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