

# Toward Robust Patient-Specific Quality Assurance for Magnetic Resonance-Guided Online Adaptive Radiation Therapy

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## ABSTRACT

**Purpose:** To develop and evaluate a log-file-based PSQA method for the ViewRay MRIdian MR-Linac that incorporates actual machine delivery information to improve the robustness of adaptive treatment plan verification.

**Methods:** RT plan and delivery log files were parsed to extract monitor units (MU), gantry angle, and multileaf collimator (MLC) positions. Segment apertures were reconstructed by interleaving the upper and lower stacks of the dual-focused, dual-stack ViewRay MLC as binary masks shifted by half a leaf width, yielding an effective resolution of 0.10 mm in the leaf motion direction and 4.15 mm in the leaf width direction at isocenter. MU-weighted beam's-eye-view fluence maps were generated per gantry angle by summing segment apertures weighted by MU. Planned and delivered fluence maps were compared using gamma analysis with a 1%/1 mm criterion. All software solutions were developed in-house.

**Results:** The method was evaluated on an adaptive intensity-modulated radiation therapy (IMRT) plan comprising 28 beam angles. Gamma analysis (1%/1 mm) of the reconstructed fluence maps yielded passing rates  $\geq 98\%$  for 27 of 28 gantry angles, with one gantry angle exhibiting a 93% passing rate.

**Conclusion:** A log-file-based PSQA method was developed for adaptive treatment plan verification on the MRIdian MR-Linac. The proposed approach provides delivery-informed plan verification and may complement independent dose calculation methods toward more robust PSQA in MR-guided radiotherapy.

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## INTRODUCTION

- In magnetic resonance-guided Linacs (MR-Linacs), patient-specific quality assurance (PSQA) is commonly performed using independent dose calculation engines due to their efficiency and compatibility with online adaptive workflows.
- However, these methods do not explicitly incorporate linac delivery performance.
- This work introduces a log-file-based, delivery-informed PSQA framework tailored to magnetic resonance-guided online adaptive radiotherapy on the ViewRay MRIdian MR-Linac.

## METHODS AND MATERIALS

- The proposed method involves three main steps (Fig. 1): parsing information from the plan and delivery log files, reconstructing 2D fluence maps for each beam angle, and evaluating the fluence maps using gamma analysis.
- Data parsing included segment-level monitor units (MU), gantry angle, and MLC positions.
- To reconstruct the fluence, segment apertures were generated by interleaving the upper and lower stacks of the dual-focused, dual-stack ViewRay MLC as binary masks shifted by half a leaf width, yielding a computational fluence grid resolution of 0.10 mm in the leaf-motion direction and 4.15 mm in the leaf-width direction at isocenter.
- MU-weighted beam's-eye-view fluence maps were generated for each beam angle by summing segment apertures weighted by MU.
- Gamma index method was implemented to evaluate the plan and delivery reconstructed fluence maps using a 1%/1 mm criterion with a 10% threshold.
- The method was evaluated on one adaptive plan for a patient treated with MRIdian MR-Linac.

## RESULTS

- Planned and delivered 2D fluence maps appeared visually similar for a representative beam angle, as shown in Fig. 2.
- Gamma analysis using a 1%/1 mm criterion with a 10% fluence threshold demonstrated passing rates  $\geq 98\%$  for 27 of 28 gantry angles, with one gantry angle below 95% (Fig. 3).
- The gantry-wise gamma passing rate distribution demonstrated consistent agreement across beam angles, with only one localized reduction below the 95% passing threshold.

## CONCLUSIONS

- A log-file-based PSQA method was developed and evaluated for adaptive treatment plan verification on the MRIdian MR-Linac.
- Unlike conventional independent dose calculation-based PSQA, the proposed method explicitly incorporates actual machine delivery information.
- This approach may complement existing PSQA methods by incorporating delivery information without disrupting online adaptive workflows.

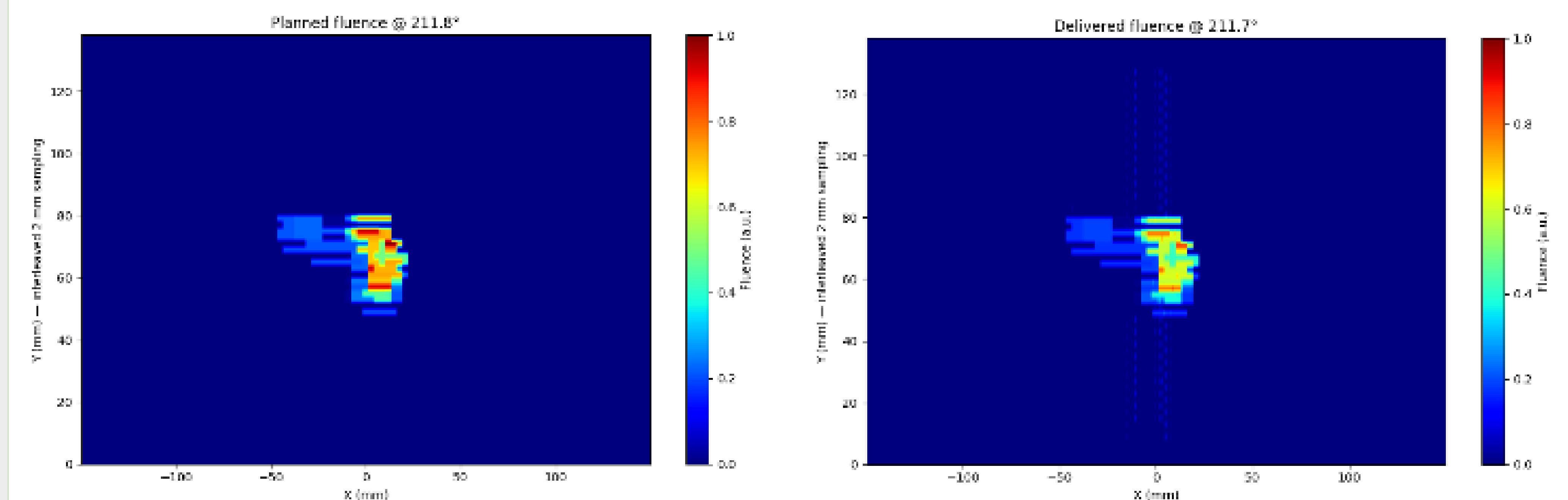


Figure 2. Planned fluence map (a), delivered fluence map reconstructed from log files (b) for a representative beam angle.

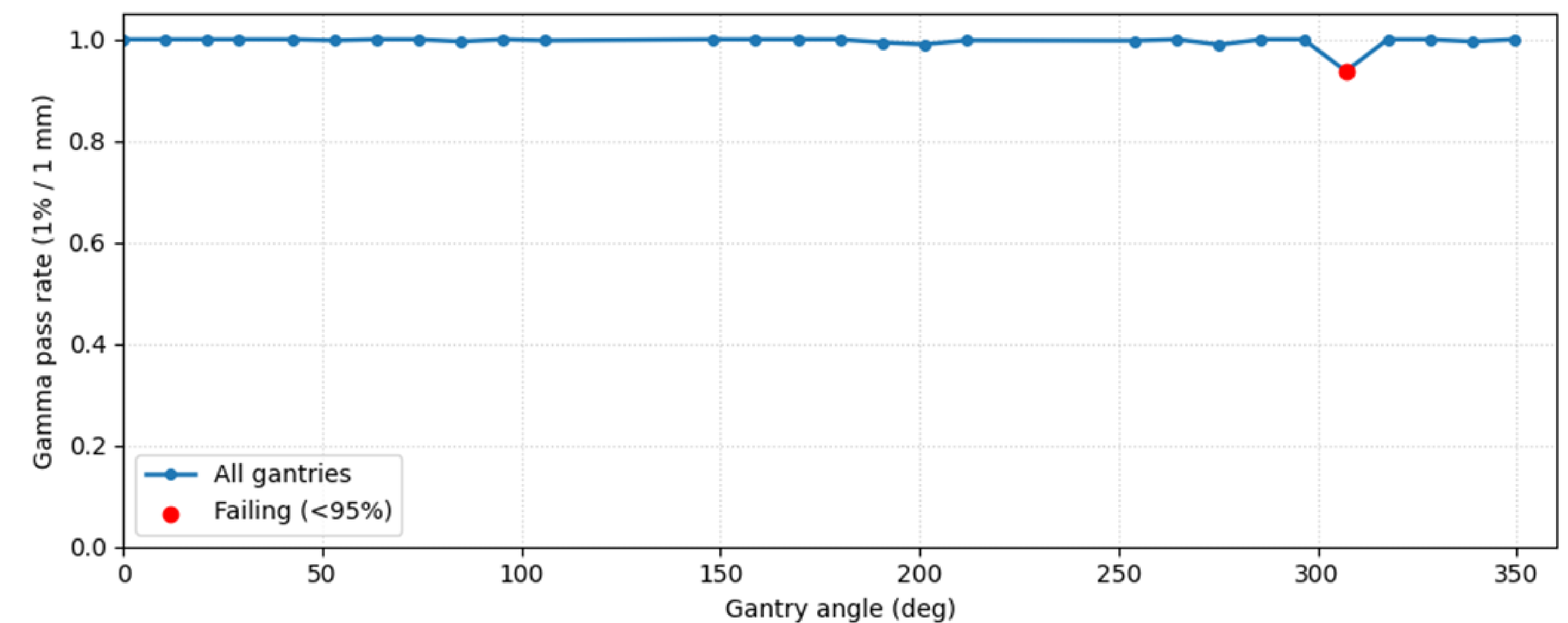


Figure 3. Gantry-wise gamma passing rates for planned versus log-derived delivered fluence maps using a 1%/1 mm criterion with a 10% fluence threshold. Passing rates were  $\geq 98\%$  for 27 of 28 gantry angles, with one gantry angle below 95%.

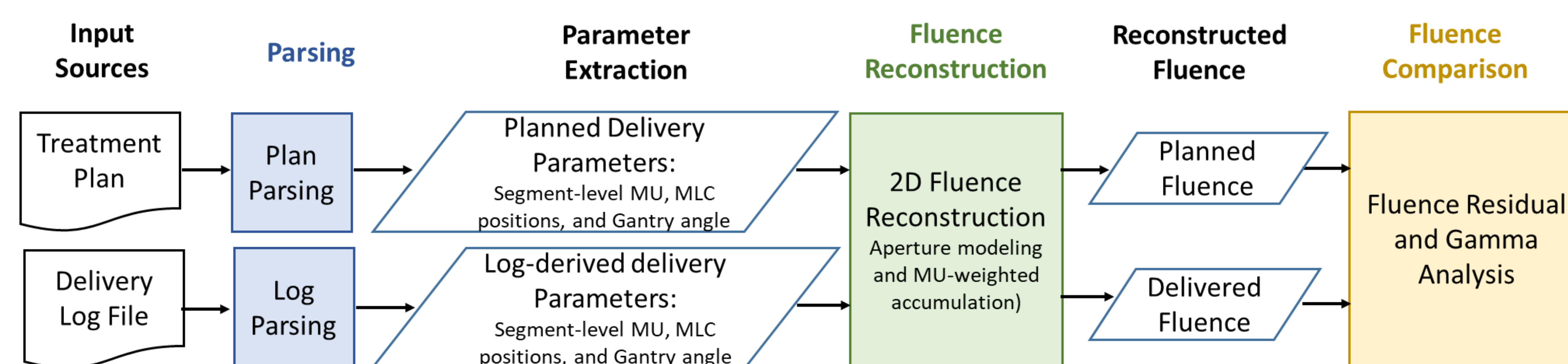


Figure 1. Log-file-based fluence verification workflow for patient-specific IMRT QA.

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