Automated Log-File–Based Quality Assurance of MLC Positional Accuracy for a Magnetic Resonance–Guided Linear Accelerator

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ABSTRACT

Purpose: To develop and evaluate an automated, log file–based MLC positional accuracy QA method for routine and longitudinal assessment of MLC performance on the ViewRay MRIdian MR-Linac system.

Methods: Four picket fence plans were generated in the ViewRay MRIdian treatment planning system at gantry angles of 0°, 90°, 180°, and 270° and delivered on the ViewRay MRIdian MR-Linac equipped with a dual-stack, dual-focused 138-leaf MLC. Each plan consisted of 11 segments with a nominal 6-mm leaf gap. An automated QA pipeline was developed in Python to parse treatment plan reports and delivery log files and perform a comprehensive analysis. Due to the unique ViewRay MLC design, upper and lower MLC stacks were analyzed independently. QA metrics included per-leaf and per-segment maximum absolute positional errors, as well as the overall maximum error relative to nominal planned positions.

Results: The maximum absolute deviation across all leaves was ≤0.3 mm, satisfying both the AAPM TG-142 action limit (±1 mm) and the more stringent AAPM MPPG 8.b. action level (±0.5 mm). Higher localized deviations were consistently observed at segments 2 and 10 and at gantry angles of 90° and 270°, consistent with expected gantry-angle dependence. Longitudinal analysis across two QA runs demonstrated stable MLC performance, with effective identification of outliers exceeding warning and action thresholds.

Conclusion: An automated, log-file–based MLC QA framework was developed for the ViewRay MRIdian MR-Linac, enabling efficient routine and longitudinal performance evaluation. The method supports integration into weekly or monthly QA workflows, with film-based methods reserved for annual independent verification.

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INTRODUCTION

- Routine verification of multileaf collimator (MLC) performance is essential for the safe delivery of highly modulated radiotherapy on MR-Linacs.
- MR-Linac systems that are not equipped with an electronic portal imaging device rely primarily on film-based MLC quality assurance (QA), which is labor-intensive and time-consuming.
- This work introduces an automated, log-file–based MLC positional accuracy QA framework tailored to the unique dual-stack, dual-focused 138-leaf MLC design of the ViewRay MRIdian MR-Linac.

METHODS AND MATERIALS

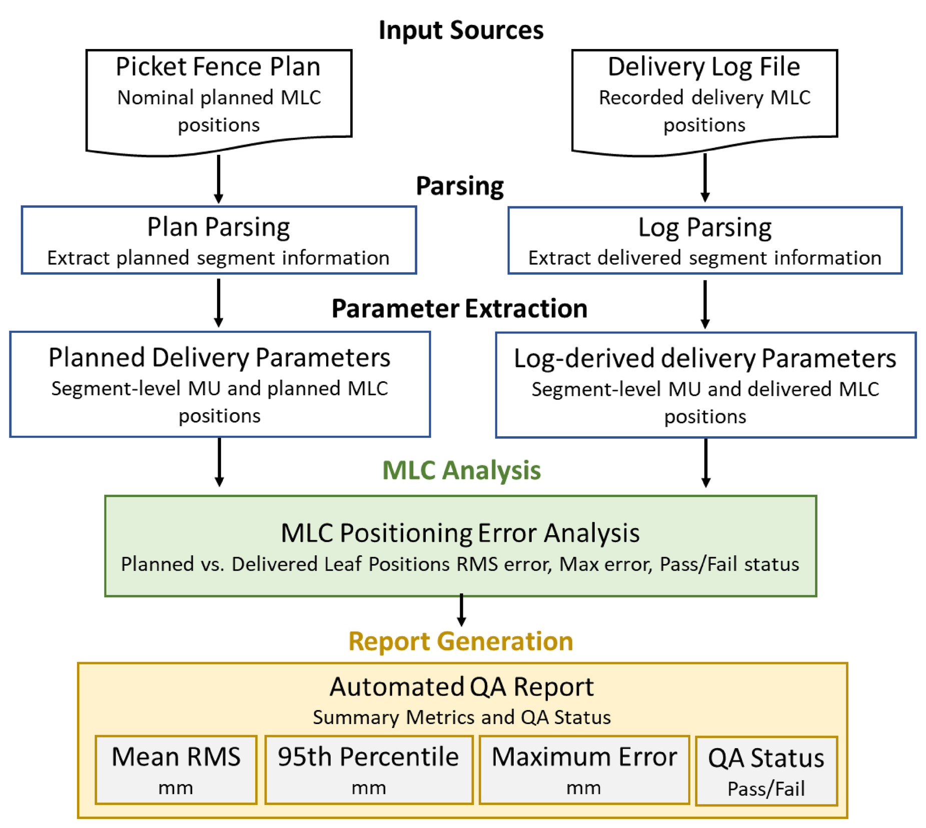

Figure 1. Log-file–based MLC positioning QA workflow.

- The framework integrates automated data parsing, error quantification, visualization, and report generation (Fig. 1).
- It was tested on four picket fence plans generated in the ViewRay MRIdian TPS at gantry angles of 0°, 90°, 180°, and 270° and delivered on the ViewRay MRIdian MR-Linac equipped with a dual-stack, dual-focused 138-leaf MLC.
- Each plan consisted of 11 segments with a nominal 6-mm leaf gap.
- Due to the unique ViewRay MLC design, upper and lower MLC stacks were analyzed independently.
- Leaf evaluation metrics included per-leaf RMS error, per-leaf maximum absolute error, per-segment maximum absolute error, and overall maximum error relative to nominal planned positions.
- A Streamlit-based graphical user interface was developed for MRIdian MLC QA and automated report generation.

RESULTS

- The absolute leaf positions relative to isocenter are visualized as virtual picket fence patterns for each of the 11 segments (Fig. 2), enabling visual identification of abnormal leaf positions.
- Across all gantry angles and segments, the maximum absolute per-leaf MLC positional error was ≤0.3 mm (Fig. 3), well within both the AAPM TG-142 action limit (±1 mm) and the AAPM MPPG 8.b. action level (±0.5 mm).
- Longitudinal analysis across two QA runs (Fig. 4) showed stable MLC performance over time, with clear visualization and automated flagging of deviations exceeding warning and action thresholds.

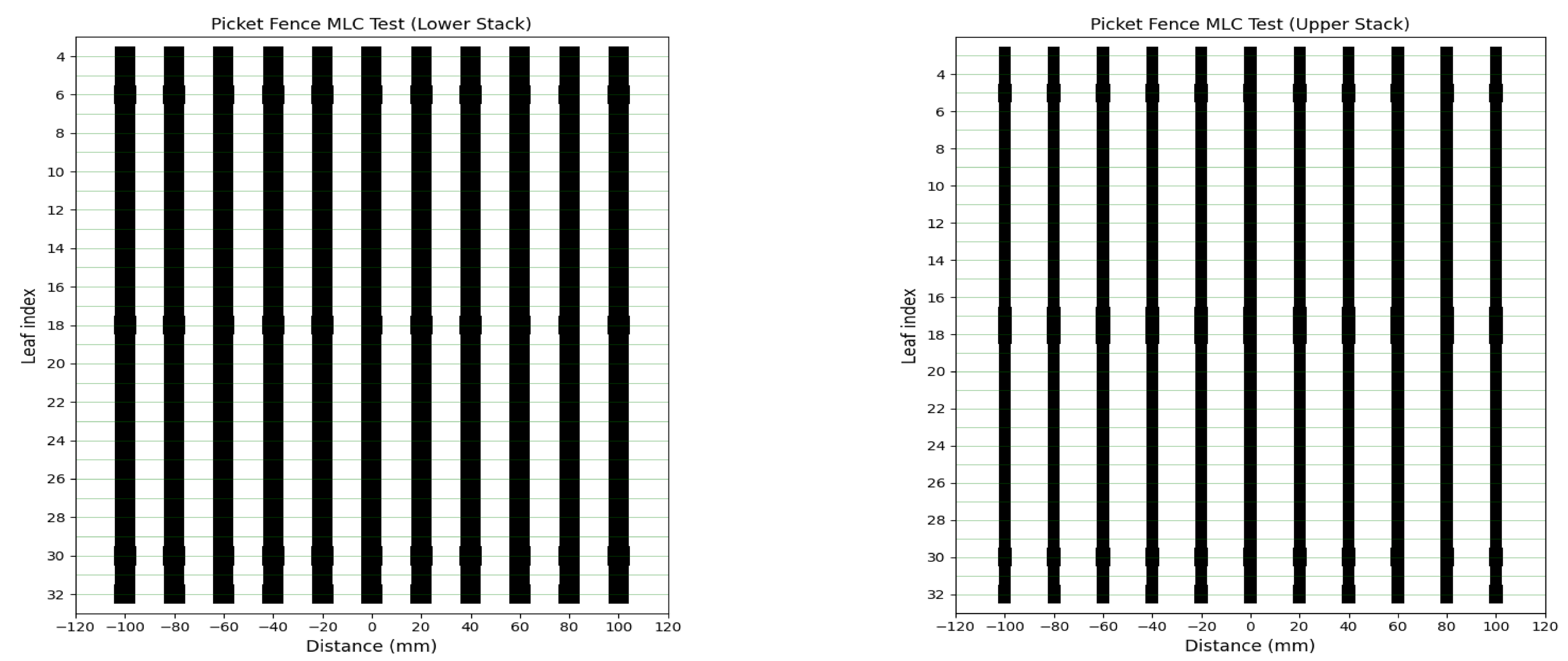

Figure 2. Virtual picket fence patterns for one gantry angle of 90°, shown separately for the upper (left) and lower (right) MLC stacks.

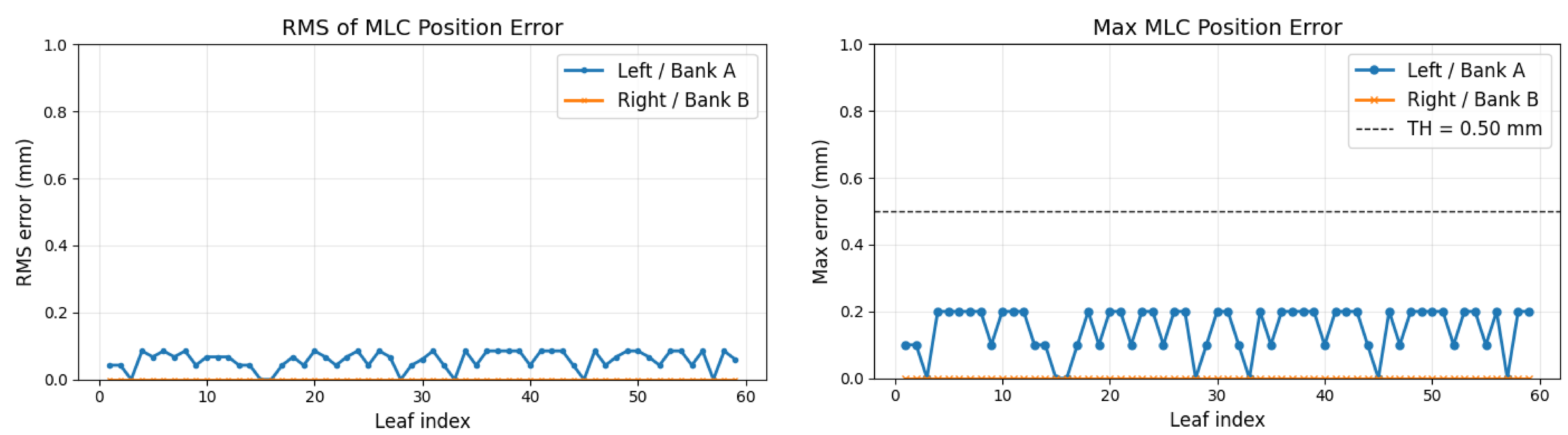

Figure 3. RMS per-leaf MLC error (left) and maximum per-leaf MLC error (right) across 11 segments for one gantry angle of 90°.

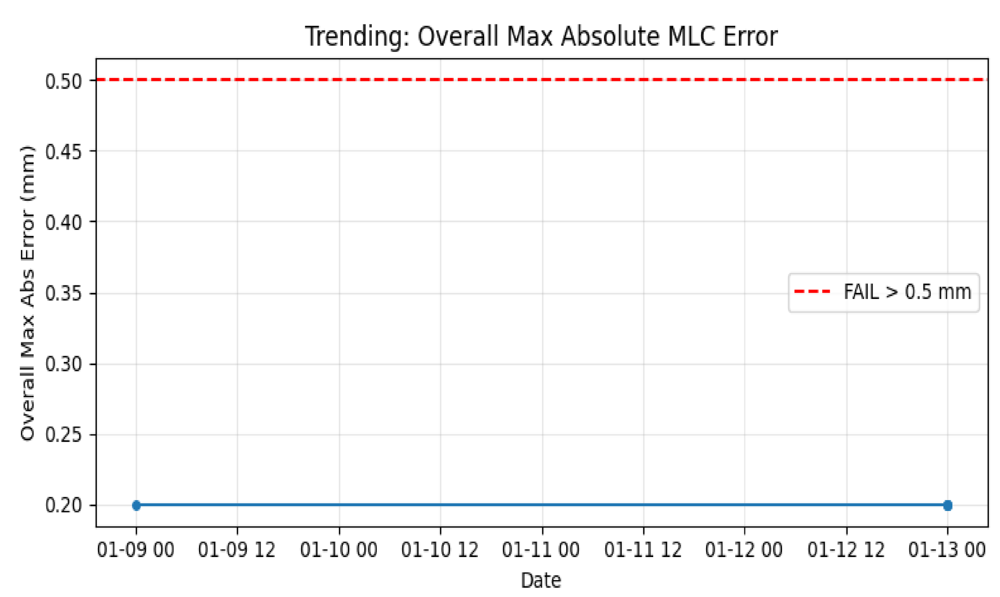

Figure 4. Longitudinal overall maximum absolute MLC error with a 0.5 mm action threshold.

CONCLUSIONS

- The proposed framework enables efficient, delivery-log–based assessment of MLC positional accuracy for routine and longitudinal QA on the MRIdian MR-Linac.
- The method supports integration into weekly or monthly QA workflows and may reduce reliance on film-based measurements for routine MLC QA.
- This approach reduces QA workload while enhancing sensitivity to subtle and progressive MLC deviations in MR-guided radiotherapy.

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