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JOINT AAPM | COMP MEETING

Quantification and Temporal Stability of MR-Guided Radiotherapy Gating System Latency Utilizing a Respiratory Motion Phantom: PD-DPV-T-69

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ABSTRACT

Purpose: Intrafraction motion management is essential to reduce setup uncertainty and prevent dose delivery errors during radiotherapy, particularly for tumors influenced by respiratory motion near the diaphragm. Magnetic resonance guided radiotherapy enables real-time beam gating based on direct visualization of the target. The ViewRay 0.35T MRIdian MR-Linac system offers advantages including superior soft tissue contrast, non-ionizing imaging, and flexible imaging planes. Following the A3i system upgrade, gating latency associated with target motion relative to user-defined boundaries has not been well characterized. This study quantifies beam-on and beam-off gating latency after the upgrade and evaluates its temporal stability.
Methods: Gating latency measurements were acquired over five months post-upgrade using a ModusQA QUASAR respiratory motion phantom. The phantom simulated sinusoidal respiratory motion with 6 breaths per minute and 12mm amplitude. Cine MR imaging was performed using a rigid three-plane Cartesian TRUFI sequence at 4 FPS with 3.5mm spatial resolution. Gating was defined using a 30mm margin in the superior–inferior (y) direction on the coronal plane. Phantom trigger positions were calibrated to correspond to cine-reported target excursions of less than 2% beyond the gating boundary. Beam control and phantom-based trigger signals were recorded simultaneously, and latency was determined by comparing the temporal offset between target motion and beam control waveforms.
Results: The weighted mean beam-on latency was 682.15±258.96ms, while the weighted mean beam-off latency was −436.13±272.39ms. Session-to-session variability was limited, with average beam-on and beam-off latencies differing by no more than 334ms and 224ms, respectively. Observed individual measurements of beam-on latencies ranged from 80ms to 1528ms, and beam-off latencies ranged from −979.5ms to 556ms.
Conclusion: Gating latency following the A3i upgrade was temporally stable and appropriate for clinical intrafraction motion management. Beam-off events consistently occurred prior to target excursion beyond the defined boundary, prioritizing patient safety while slightly reducing treatment efficiency.

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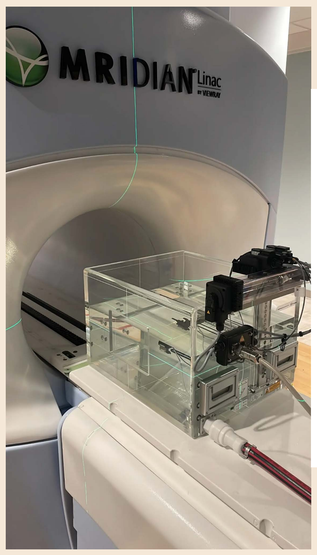
PURPOSE

- Intrafraction motion management is **essential** for reducing geometric uncertainty and preventing dose delivery errors during radiotherapy
- MR-guided radiotherapy enables real-time beam gating through direct visualization of the target
- Following the **ViewRay MRIdian A3i system** upgrade, gating latency relative to target motion had not been well characterized



Objective: To quantify beam-on and beam-off gating latency of the ViewRay 0.35T MRIdian MR-LINAC following the A3i upgrade and evaluate latency stability over time. 5 months were examined.

METHODS AND MATERIALS

- Gating latency was measured using **ModusQA QUASAR respiratory phantom**
- Phantom simulated sinusoidal respiratory motion at **6 breaths/min** with **12 mm amplitude**
- Cine MR images were acquired using a three-plane Cartesian TRUE sequence at **4 FPS with 3.5 mm spatial resolution**
- Gating boundary was **30 mm** in the superior-inferior direction on the coronial plane
- Phantom trigger positions were calibrated to correspond with cine-reported target motion relative to the gating boundary
- Beam control signals and phantom-based trigger signals were recorded simultaneously
- Latency was calculated from the temporal offset between target motion and beam control waveforms

ModusQA QUASAR

RESULTS

- Session-to-session variability was limited of the 5-month measurement period

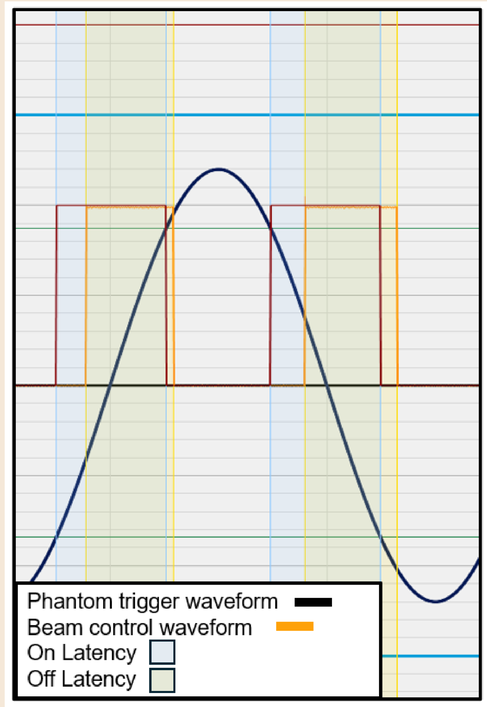
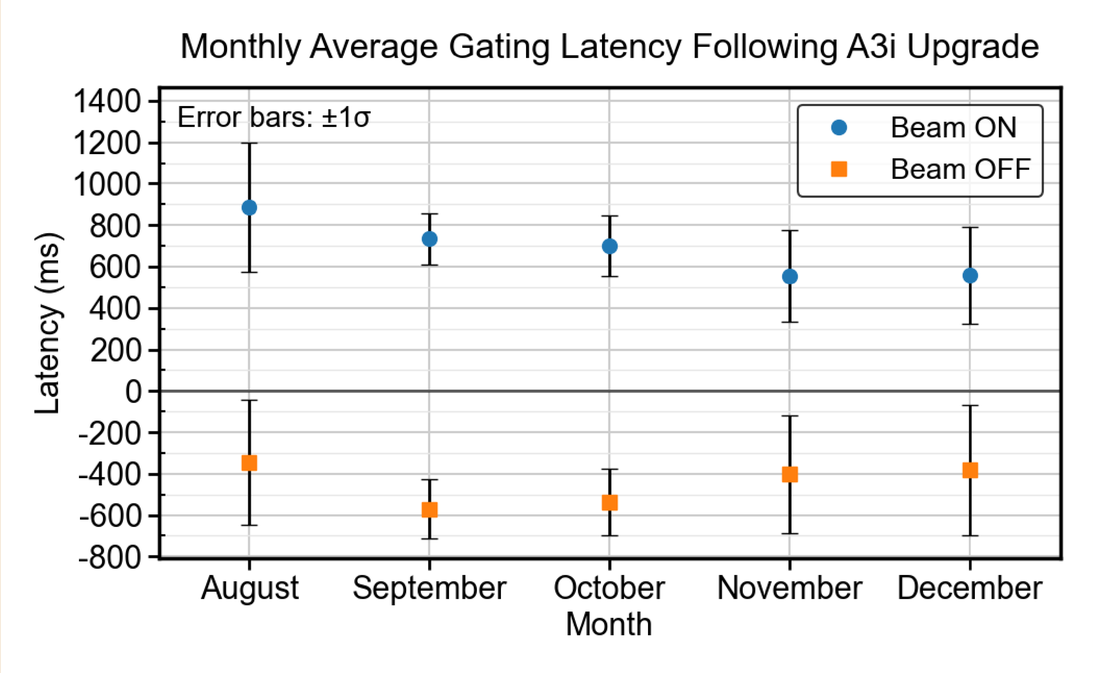


Table 1. 5-Month Latency Data.

5 Months	Weighted Mean Latency (ms)	Max Session-to-session Variability of Mean Latencies (ms)	Min Latency (ms)	Max Latency (ms)
Beam-on	682.15± 258.96	334	80	1528
Beam-off	-436.13± 272.39	224	-979.5	556



DISCUSSION/CONCLUSIONS

- Beam-on latency was longer than beam-off latency, which is clinically acceptable because **delayed beam-on primarily reduces treatment efficiency** rather than compromising target coverage
- Beam-off latency was conservative, with beam termination occurring before target excursion beyond the defined gating boundary
- The **conservative beam-off behavior prioritizes patient safety** by reducing the likelihood of irradiating outside the intended gating window
- Limited session-to-session variability suggests that the **gating latency remained temporally stabile over the 5-month evaluation period**
- The observed range of individual latency values highlights the importance of system-specific latency characterization, especially after software upgrades
- These results support the use of phantom-based gating latency measurements as part of MR-guided radiotherapy quality assurance
- Future work should evaluate more complex reparatory patterns, gating thresholds, and the effects of imaging sequence parameters on gating latency

Conclusions:

- MRIdian gating latency following the A3i upgrade was temporally stable
- Beam-off events occurred before target excursion beyond the defined gating boundary
- The observed behavior prioritizes patient safety, although it may slightly reduce treatment efficiency

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