

Quantitative Assessment of an Intra-Fractional Online MR-Guided Adaptive Workflow: Stop, Scan, and Adapt

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PURPOSE / OBJECTIVES

- ❑ The Stop-Scan-Adapt (SSA) feature introduced with the MRIdian A3i upgrade enables intra-fractional (partial) adaptation during online MR-guided adaptive radiotherapy (ART) through rapid re-optimization without patient repositioning.
- ❑ While SSA efficiently responds to anatomical changes or interruption during delivery, its dose accounting methodology and clinical interpretation are not well characterized. This study evaluates the SSA workflow, dose handling, and deformation-related dose uncertainty.

MATERIAL & METHODS

- ❑ A retrospective MR-guided adaptive treatment plan was delivered to a motion phantom (Fig. 1) containing a moving insert as a target surrogate. Online adaptation followed target contour modification.
- ❑ Partial dose delivery preceded 1cm superior target displacement to simulate internal motion. SSA was initiated, a new MR image acquired, target-related structures updated, and re-optimization performed.
- ❑ Two delivery scenarios were evaluated:
 - Scenario 1:** 10% of dose delivered prior to SSA
 - Scenario 2:** 30% of dose delivered prior to SSA.
- ❑ Delivered MUs, SSA QA reports, and composite dose calculations were analyzed.

RESULTS

- ❑ In both scenarios, SSA excluded beams already delivered and re-optimized treatment using the remaining beams.
- ❑ The apparent difference in monitor units (MUs) between the SSA plan and the SSA QA report is due to SSA dose handling (Fig. 2). The pre-SSA dose is split equally between the pre-SSA and SSA images. The pre-SSA portion is deformed to the SSA image, summed with the SSA portion, and then added to the SSA-optimized plan dose to obtain the total delivered dose.
- ❑ Increasing pre-SSA delivered dose from 10% to 30% increased PTV D95% uncertainty from 1.6% to 6.5% between undeformed plan-sums and the SSA-reported composite dose, particularly in regions of induced target displacement (Fig. 3).

KEY RESULTS:

- ❑ **SSA re-optimized only the remaining, undelivered beams**, while previously delivered beams were excluded from optimization.
- ❑ **The SSA QA report accounted for delivered dose by partitioning and deforming the pre-SSA dose**, explaining the apparent MU differences between the optimized SSA plan and the QA report.
- ❑ **Agreement between offline plan summation and the SSA-reported composite dose decreased as the pre-SSA delivered dose increased**, with PTV D95% differences increasing from **1.6% to 6.5%** for 10–30% pre-SSA dose delivery (Fig. 3).
- ❑ **The largest dose discrepancies occurred near regions of intentional target shift**, consistent with deformation-based dose accumulation.
- ❑ **Local gamma analysis (2 mm/2%, 10% threshold) demonstrated high agreement** between undeformed plan sums and SSA-reported composite doses (**94.3%** and **92.1%** for Scenarios 1 and 2, respectively).

SUMMARY / CONCLUSION

- ❑ SSA enables efficient intra-fraction adaptation but relies on **deformation-based dose accumulation**, which may introduce dose **uncertainty** when **substantial dose** is delivered **before adaptation**.
- ❑ Understanding how SSA partitions and deforms delivered dose is essential for accurate QA report interpretation and plan evaluation.
- ❑ This work provides a practical framework for understanding SSA dose accounting and identifying scenarios with increased uncertainty.
- ❑ These findings support safer clinical implementation of MR-guided adaptive radiotherapy and highlight the importance of structured multidisciplinary training.

