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# Reducing IMRT Delivery Times by Accelerating Segment Loading and MLC Positioning for the 1.5 T MR-linac

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## INTRODUCTION

Today, magnetic resonance imaging (MRI)-guided radiotherapy workflows are time-consuming [1, 2] since:

- Intensity modulated radiotherapy (IMRT) is the current standard delivery technique on MR-linacs.
- The IMRT delivery cycles through the radiating and moving segments resulting in delivery efficiencies of 30–70%.

## AIM

To investigate and validate optimizations to the treatment control system (TCS) of a 1.5 T Unity MR-linac (Elekta AB, Stockholm, Sweden) to reduce the non-radiating time of IMRT plan deliveries while maintaining accuracy.

## MATERIALS AND METHODS

Twenty clinical IMRT plans consisting of 5 patient plans for each of the following treatment schemes:

- 20×3.1 Gy prostate
- 5×7.25 Gy prostate
- 5×8 Gy pancreas
- 23×1.8 Gy esophagus

Two optimizations were made to the TCS:

1. Finite state machine improvements reduced communication overhead during segment loading.
2. Multileaf collimator (MLC) motor controller optimizations improved stability at higher leaf speeds, increasing the maximum speed from 6.0 cm/s to 12.5 cm/s.

The 20 treatment plans were delivered in clinical mode and using either or both TCS optimizations combined (Figure 1).
Analysis involved (Figure 2):

- Linac log files to extract the delivery time, number of segments, maximum leaf travel distance, and positioning precision.
- Dosimetry using the Delta4 Phantom+ MR (ScandiDos, Sweden).
- Quality assurance (QA) stripe tests using the electronic portal imaging device (EPID) for MLC positioning accuracy for the different treatment delivery modes [3].

### Intensity modulated radiotherapy plan delivery

| Mode | | | | |
|---|---|---|---|---|
| 1. Clinical | Load radiating segment → | Radiating → | Load moving segment → | MLC positioning |
| 2. Faster segment loading | Load radiating segment → | Radiating → | Load moving segment → | MLC positioning |
| 3. Faster MLC positioning | Load radiating segment → | Radiating → | Load moving segment → | MLC positioning |
| 4. Faster segment loading + Faster MLC positioning | Load radiating segment → | Radiating → | Load moving segment → | MLC positioning |

*Figure 1: Schematic overview of the four different treatment delivery modes of clinical intensity modulated radiotherapy plans.*

### Analysis

| Linac log file | | | | | Dosimetry (Delta4) | QA stripetest (EPID) |
|---|---|---|---|---|---|---|
| Radiating segment duration | Non-radiating segment duration | Number of segments | Maximum leaf travel distance | Diaphragm and leaf positioning precision | Global gamma (2%/2mm) | MLC accuracy |

*Figure 2: Schematic overview of the performed analysis for clinical and accelerated intensity modulated radiotherapy plan deliveries.*

## Results (I)

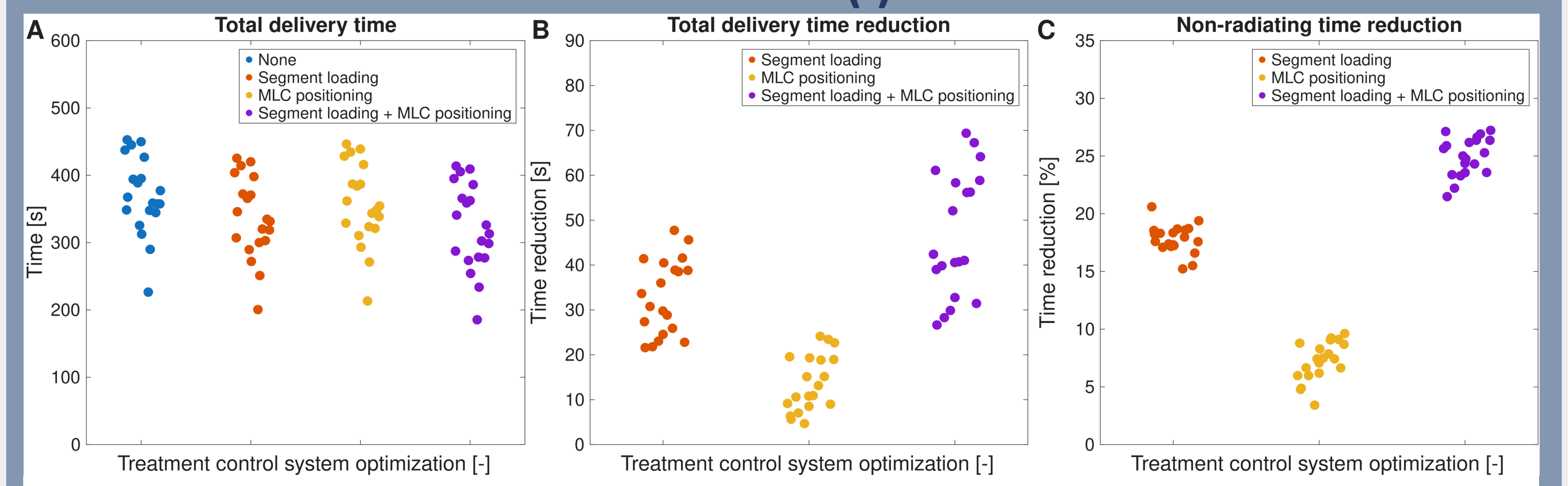


*Figure 3: Summary of the A) total delivery times, B) absolute delivery time reductions, C) and relative non-radiating time reductions across twenty clinical intensity modulated radiotherapy treatments plans for different treatment control system optimizations.*

Clinical delivery times were:

- 326–377 s (20×3.1 Gy prostate)
- 358–450 s (5×7.25 Gy prostate)
- 389–453 s (5×8 Gy pancreas)
- 227–348 s (23×3.1 Gy esophagus)

The optimizations reduced the delivery times by 27–69 s, corresponding to 21–27% of the non-radiating time (Figure 3).

- Faster segment loading: 22–48 s (15–21%)
- Faster MLC positioning: 5–24 s (3–10%)

No difference in radiating time (≤1% difference)

## Results (II)

- Time reductions due to faster segment loading increased linearly with the number of IMRT plan segments
- Time reductions due to faster MLC positioning increased linearly with the leaf travel distance

Median (25th–75th percentile) non-radiating segment time reductions were 1.0 (0.8–1.1) s (Figure 4).

- Faster segment loading: 0.7 (0.6–0.8) s.
- Faster MLC positioning: 0.2 (0.2–0.4) s.

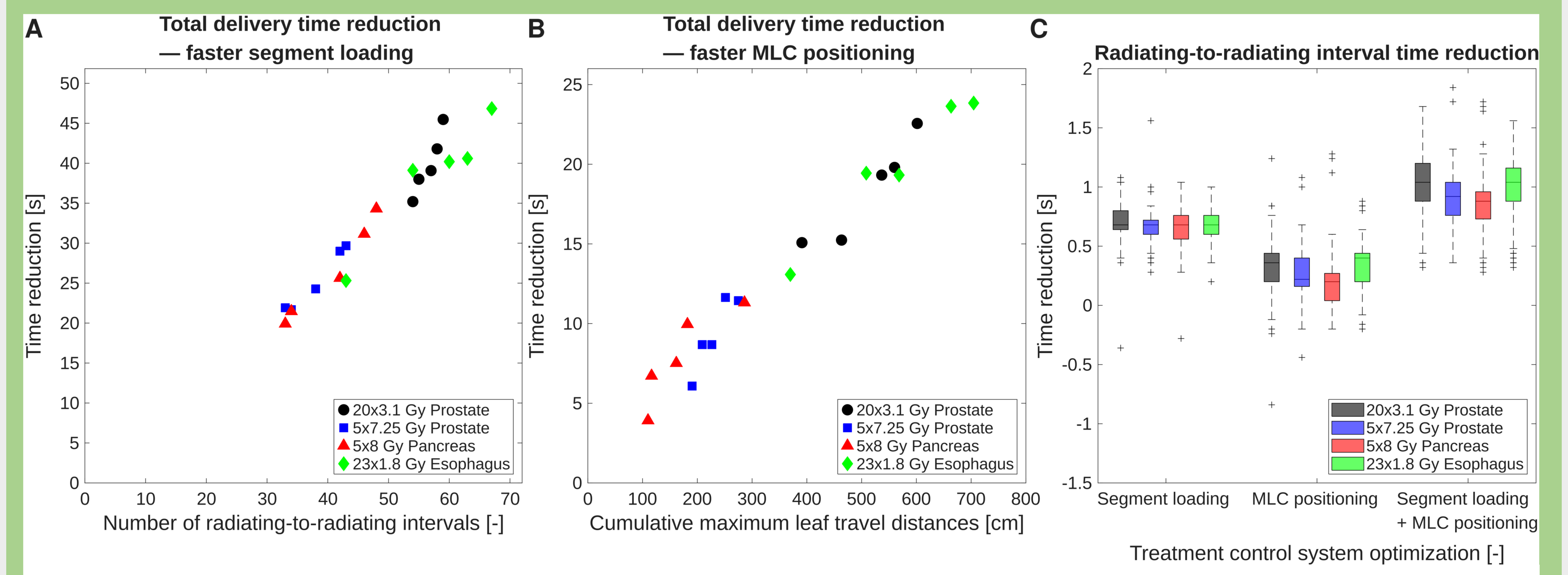


*Figure 4: Summary of the delivery time reductions as function of explanatory variables for faster segment loading (A) and multileaf collimator (MLC) positioning (B). Distributions of time reductions per radiating-to-radiating interval are summarized for four different treatment indications for the different treatment control system optimizations.*

## Results (III)

- Diaphragm and MLC precision below 0.2 mm.
- Global gamma pass-rates ≥ 98%.

## Results (IV)

Stripe test revealed for the center 30 leaf pairs:

- Absolute positioning error below 0.2 mm.
- Relative positioning error within 0.13.

## CONCLUSIONS

The non-radiating durations can be safely reduced by the improved segment loading and MLC positioning. More complex IMRT treatment plans that are typically characterized by low MU per radiating segment and larger total leaf travel distances, benefit more from the demonstrated TCS optimizations.

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## REFERENCES

[1] Westerhoff et al., 2025, https://doi.org/10.1016/j.ctro.2024.100901
[2] Güngör et al., 2021, https://doi.org/10.1016/j.prro.2020.07.003
[3] Sastre-Padro et al., 2004, https://10.1088/0031-9155/49/12/011

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