# Impact of Online Adaptive Proton Therapy on Linear Energy Transfer in Head-and-Neck Cancer Under Daily Anatomic Variation

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2026 JULY 19–22 VANCOUVER, BC
JOINT AAPM | COMP MEETING

Mass General Brigham Cancer Institute
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## ABSTRACT

**Purpose:** To quantify the effect of interfractional anatomic variation on dose-averaged linear energy transfer ($LET_d$) in head-and-neck intensity-modulated proton therapy and determine whether daily adaptive proton therapy further alters $LET_d$ compared with non-adaptive treatment.

**Methods:** Three-field IMPT plans were evaluated retrospectively for 18 patients across 576 daily CBCT-based anatomies. Non-adaptive (NA) delivery of the nominal plan and online adaptive (OA) delivery using a validated in-house dose-restoration workflow were forward-calculated using Monte Carlo. Dose-volume metrics, mean $LET_d$, and voxel-wise maximum $LET_d$ were compared across anatomical structures.

**Results:** Online adaptation substantially restored target coverage under daily anatomic variation, whereas differences in $LET_d$ metrics between non-adaptive and adaptive treatment were minimal across the cohort.

**Conclusion:** $LET_d$ remained generally stable under interfractional anatomic variation and online adaptation. The nominal treatment plan may therefore predict $LET_d$ reliably for most patients, although monitoring may remain warranted in outlier cases with large anatomic changes.

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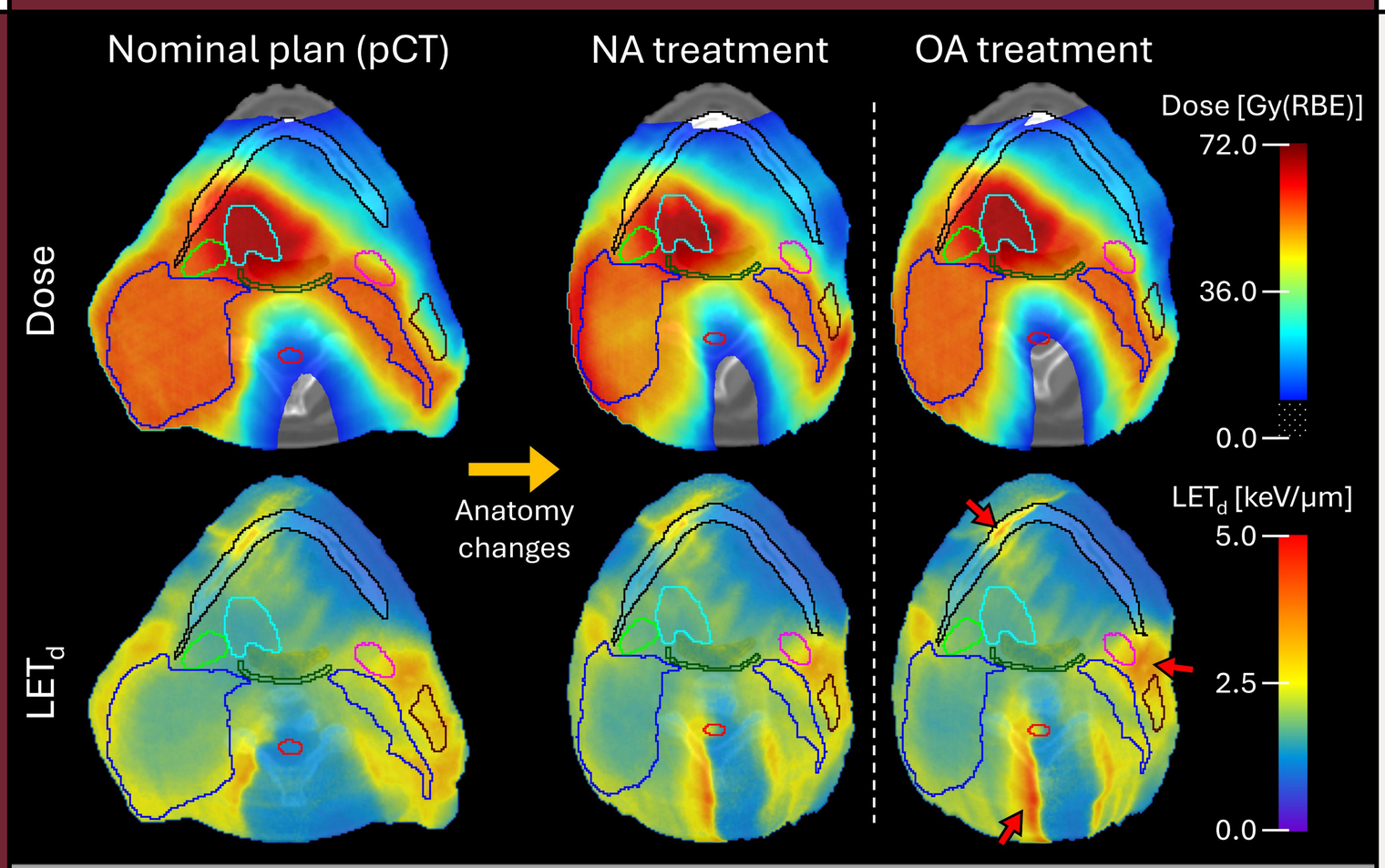


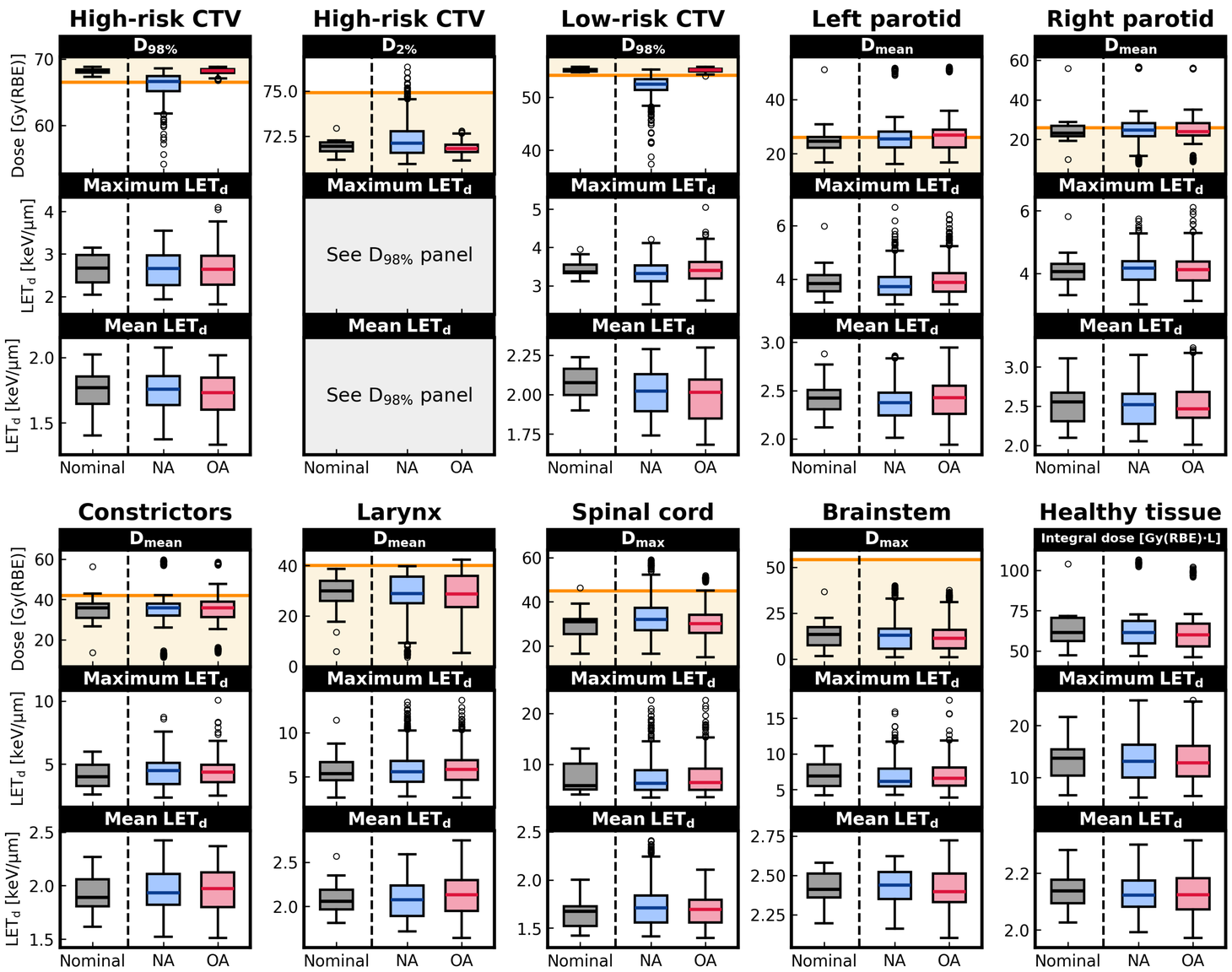


## BACKGROUND

- Online adaptive proton therapy has started to enter clinical practice [1].
- LET-guided optimization has been explored at the initial planning stage [2], but the impact of daily anatomic variation on $LET_d$ remains unclear.
- We used daily imaging to assess how interfractional anatomic variation perturbs $LET_d$ and whether online adaptation (OA) further modifies $LET_d$ relative to non-adaptive (NA) delivery.
- OA was simulated using a previously validated dose-restoration workflow [3,4].

## KEY FINDINGS

1. Representative outlier (**Figure 1**): OA restored target coverage, while localized areas of elevated $LET_d$ appeared relative to NA and the nominal plan.
2. Across all 576 fractions (**Figure 2**), absolute OA–NA differences in cohort-averaged mean and maximum $LET_d$ remained ≤0.04 and ≤0.15 keV/μm, respectively.

**For most patients, the nominal plan on pCT provides a reliable estimate of $LET_d$**

## REFERENCES

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