Decision Support for Adapt-on-Demand Adaptive Radiotherapy for Head and Neck Cancer

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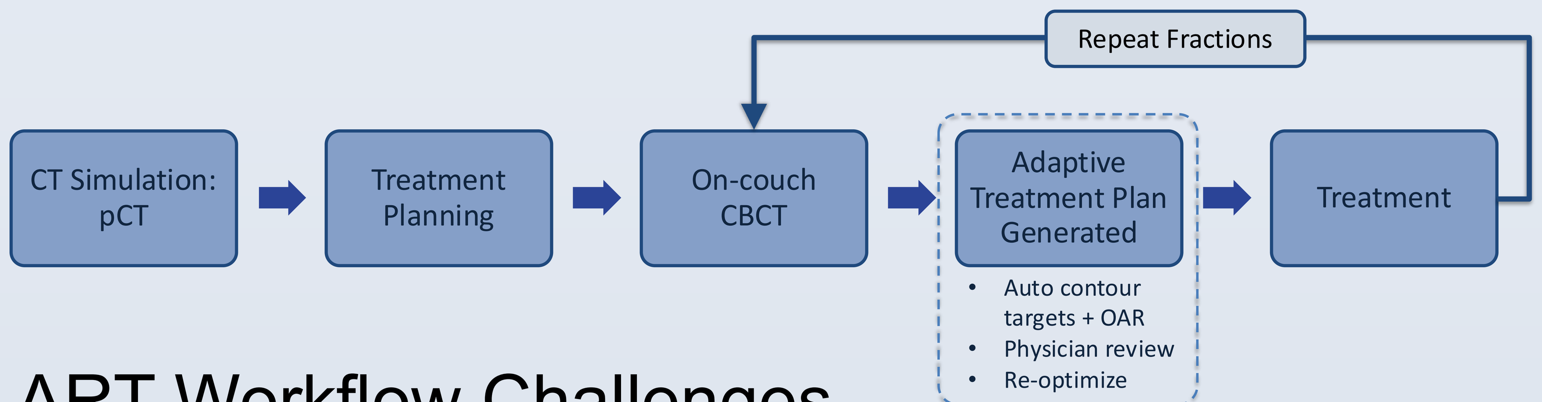
Introduction and Purpose

Background

- **Adaptive Radiotherapy (ART):** adjusts treatment plan from planning CT (pCT) to the anatomy-of-the-day using on-couch cone beam CT (CBCT)
- Improves dose distribution in sites with significant anatomical changes, like head and neck (HN) tumors



ART Workflow Challenges

- Time-intensive: adaptive procedure is done while the patient is on the couch (~30 min)
- Resource-intensive: real-time planning/optimization/ review, clinician involvement

Gap

- Unclear when adaptation is necessary or beneficial
- Current adaptive systems lack decision support

Purpose

- Quantify dosimetric variation associated with tumor regression during HN radiotherapy
- Evaluate the benefit of adaptive replanning as a basis for adapt-on-demand decision support

Results

- Non-ADP plans resulted in a slight degradation of plan quality, characterized by an increased mean D50% to ipsilateral parotid by 0.3 Gy.
- ADP plans significantly improved OAR sparing, reducing ipsilateral parotid D50% by 8.4 Gy and oral cavity D50% by 6.7 Gy for the final stage of tumor volume.
- ADP plans showed better overall PTV HI of 6.1%, 5.7%, 5.7%, 5.0% across all stages while non-ADP HI were 5.6%, 6.4%, 7.0%, 7.2%.

Figures 1 and 2 show improved dose conformality and associated organ-at-risk (OAR) sparing with adaptive replanning for cases 1 and 5, respectively.

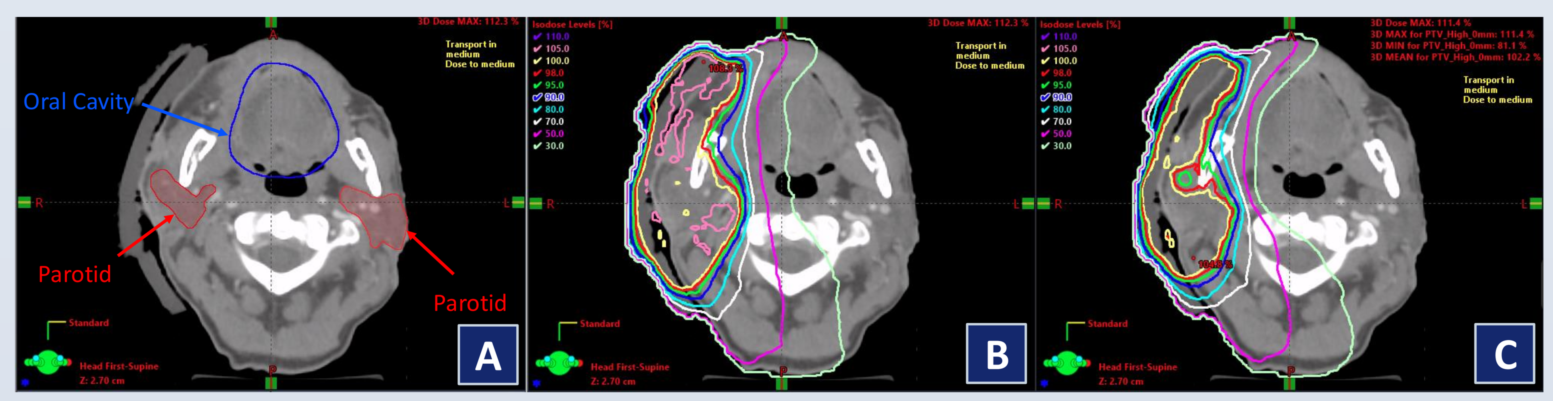


Figure 1: Case 1: (A) Oral cavity and parotid contours. (B) Non-ADP plan (C) ADP plan

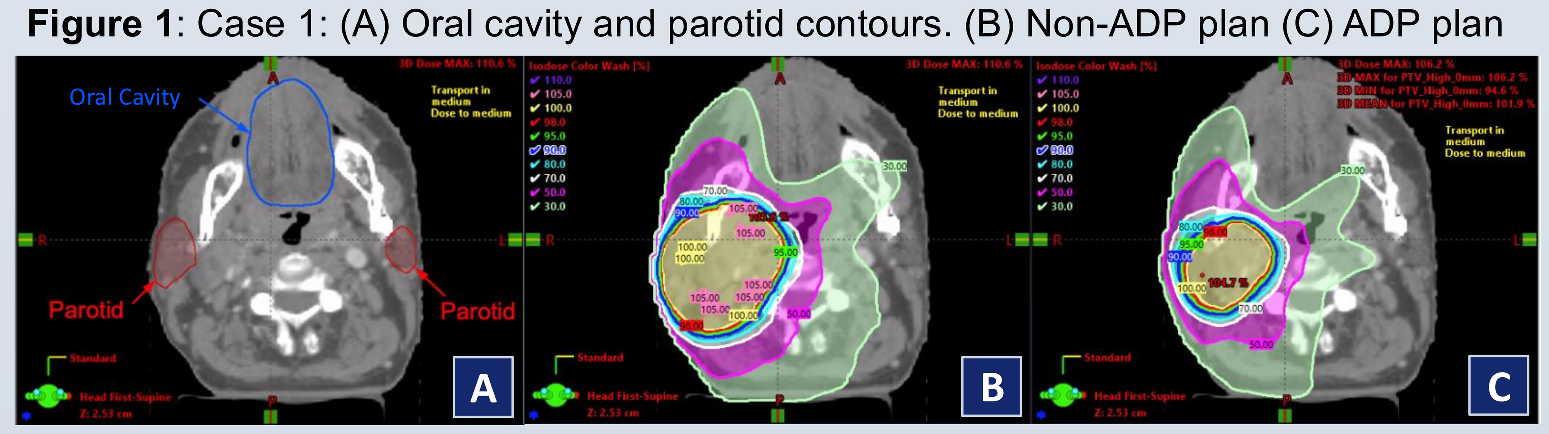
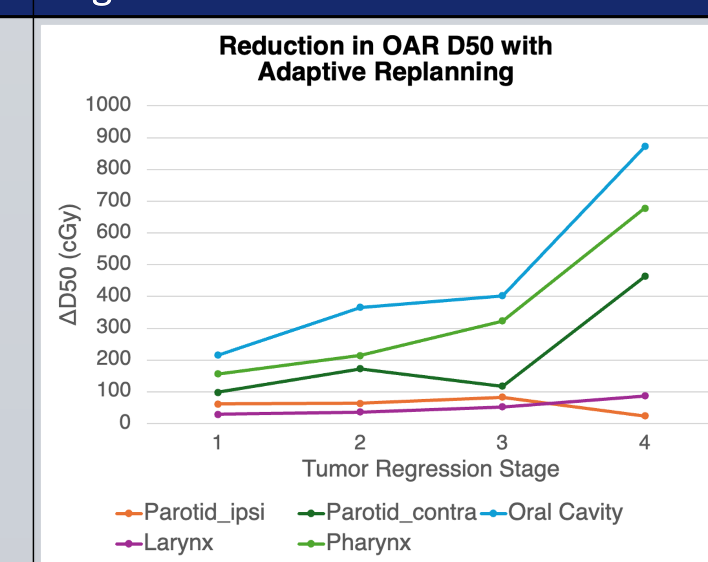
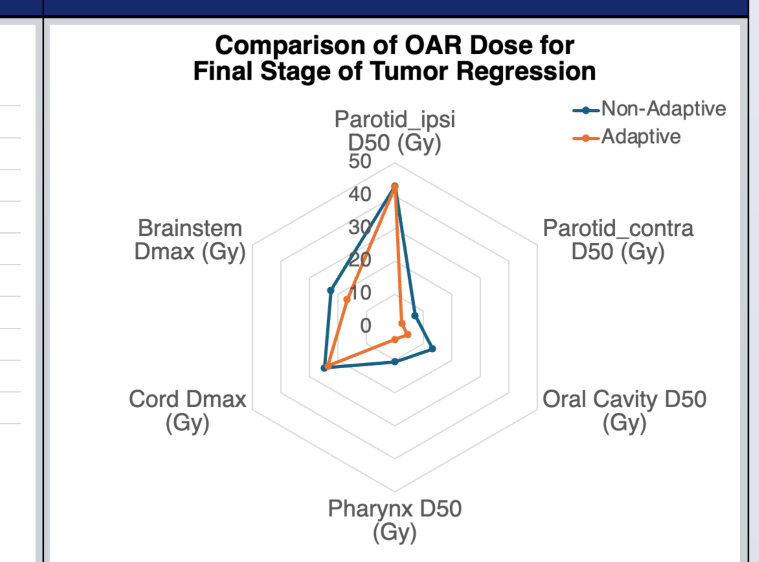
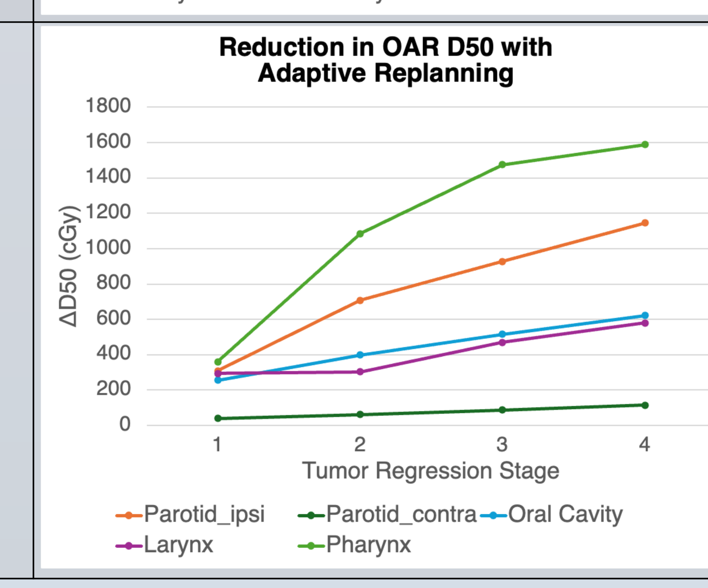
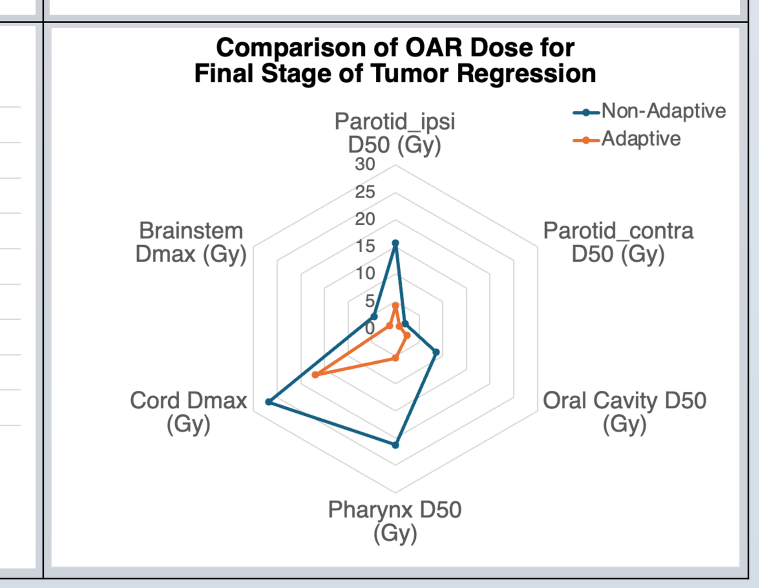


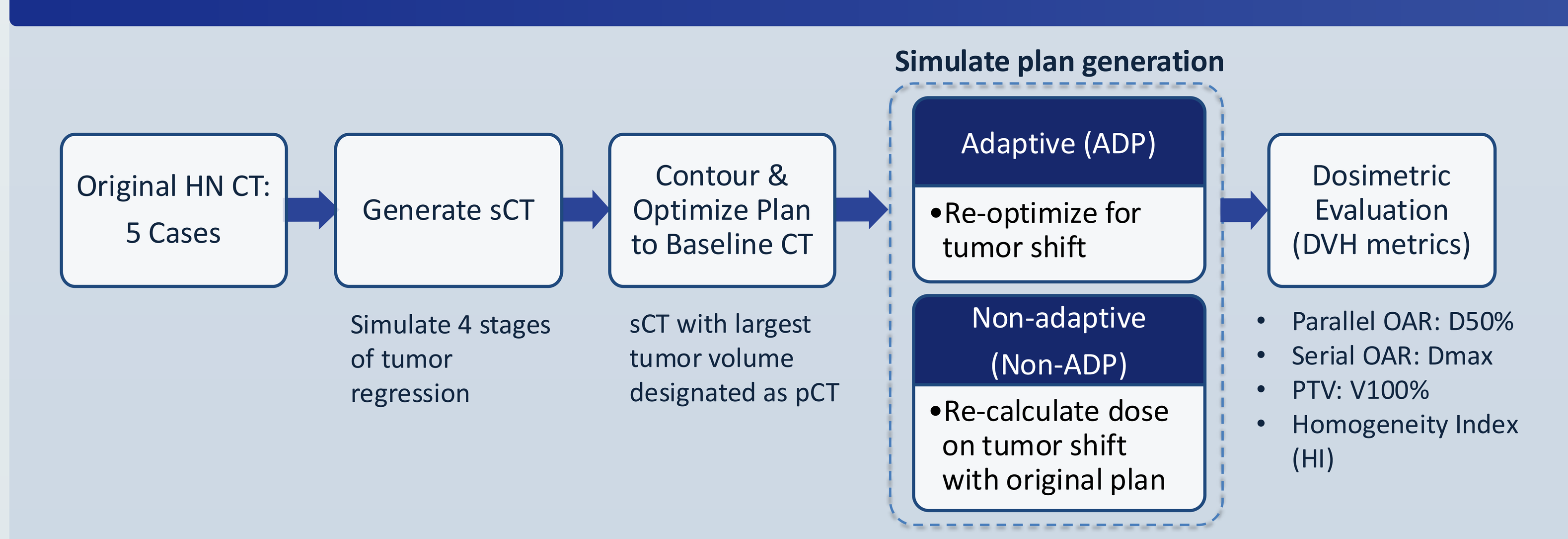
Figure 2: Case 5: (A) Oral cavity and parotid contours. (B) Non-ADP plan (C) ADP plan

ADP plans achieved substantial improvement in OAR sparing over non-ADP plans for the final stage tumor volume, as demonstrated in Table 2.

Table 2: Dose evaluation of OAR sparing for cases 1 and 5. The plots on the left show parallel organ sparing at each tumor regression level. The spider plots on the right show the relative OAR dose of the adaptive to the non-adaptive plan for the final stage of tumor regression.

Case #	Parallel OAR Sparing with Tumor Regression Level	Comparison of OAR Dose for Non-ADP vs ADP
1		
5		

Methods



Synthetic CT (sCT) Generation

Artificial Tumor Expansion:

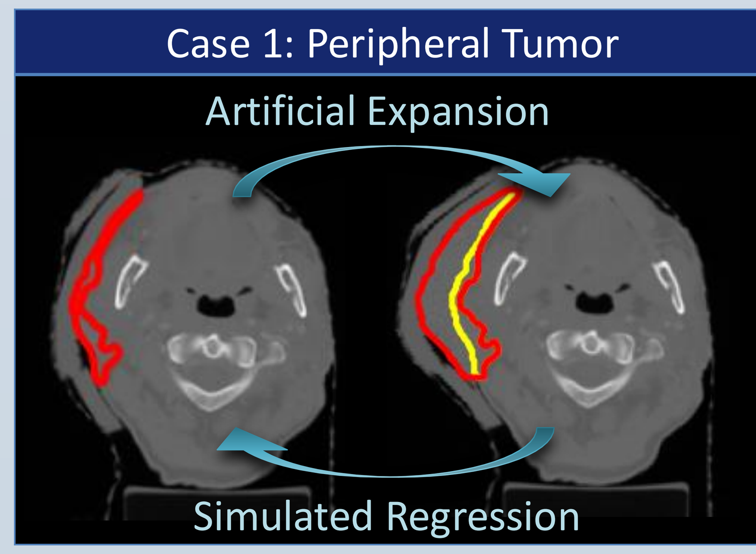
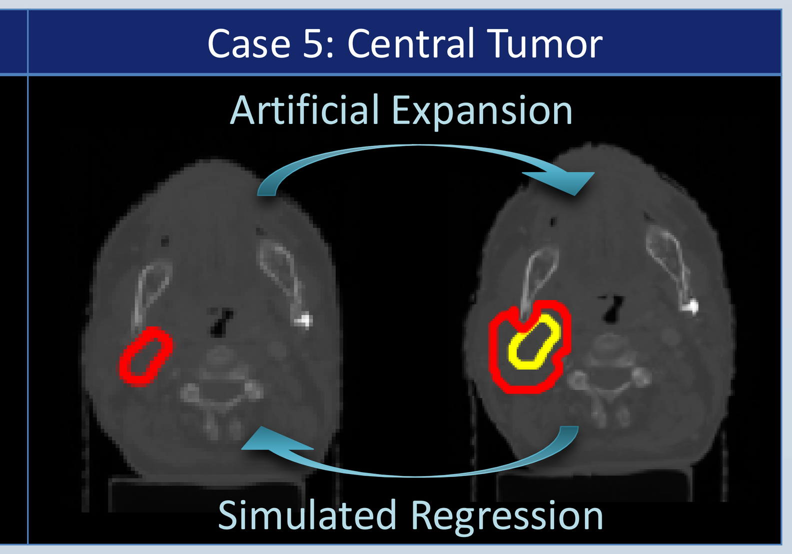
Four sCTs were generated for five HN cancer cases by progressively enlarging the tumor from the original CT.

- Peripheral tumors: directional expansion (5-20 mm)
- Central tumors: isotropic expansion (2.5-10 mm)

Simulating Tumor Regression:

Modeled by ordering datasets from largest to smallest, representing regression due to treatment fractions in four stages. The largest sCT was used as the planning CT, and the original CT represented the most regressed anatomy.

Table 1: Examples of directional expansion (case 1) and isotropic expansion (case 5) used to create the sCT dataset. For each case, the left shows the original CT and the right shows the largest expanded sCT designated as the pCT.

Case 1: Peripheral Tumor	Case 5: Central Tumor
	

Treatment Plan Generation

- Non-adaptive (non-ADP): recalculated dose to new anatomy with regressed tumor
- Adaptive (ADP): re-optimized plan for tumor regression

Dosimetric Evaluation

- D50%: parotids, oral cavity, larynx, pharynx
- Dmax: brainstem, cord
- PTV V100% and plan homogeneity index (HI)

Conclusion

Tumor regression can substantially compromise overall non-adaptive HN radiotherapy plan quality. Adaptive replanning effectively improves OAR sparing while maintaining target coverage. These findings support the feasibility of anatomy-informed decision support to identify the temporal checkpoint most likely to benefit from adaptive radiotherapy.

Future Work

Future work includes creating a predictive model of anatomy change throughout the course of treatment and integrating knowledge-based planning (KBP) based dose volume histogram (DVH) estimation to determine whether the anatomy-of-the-day is likely to benefit from adaptive replanning.