# Dual Method Quantitative QA for Head and Neck Offline Adaptive Radiotherapy Utilizing Transmission Portal Dosimetry and Contour-Based Assessment

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## OVERVIEW

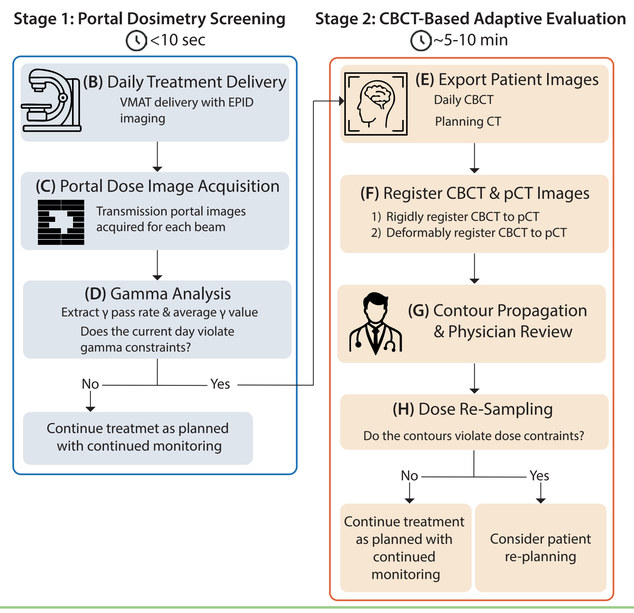
- Head & neck radiotherapy is uniquely vulnerable to anatomical change — tumor regression, weight loss, and soft-tissue deformation accumulate over treatment, threatening target coverage and increasing OAR dose
- Adaptive radiotherapy (ART) addresses these changes by modifying the treatment plan mid-course, but online ART requires high computational resources
- Offline ART depends on accurately identifying which patients need replanning — current approaches rely on manual CBCT review
- Electronic portal imaging devices (EPIDs) are standard linac equipment that can acquire transmission images every fraction with no added dose — longitudinal gamma analysis of these images can flag changes in delivered fluence that may reflect anatomical shifts, setup issues, and possibly motion
- A key challenge is distinguishing transient setup errors from true anatomical change — a tiered framework that uses portal dosimetry as a first screen, followed by targeted CBCT-based dosimetric assessment, addresses this problem efficiently

**Here, we evaluate daily portal dosimetry trends to identify patients requiring plan adaptation and perform offline adapative contouring & dosimetry to quantifiably identify patients needing re-planning**

## METHODS

### Sequential QA Framework

- For each patient, daily EPID images were first analyzed as part of a "Portal Dosimetry Screening". If Gamma constraints were violated, a "Contour Adaptive Assessment" was conducted.




### Patient Cohort

- 100 H&N cancer patients treated with VMAT on Halcyon linac (Emory University Hospital, 2023–2025)
- 6 underwent replanning due to anatomical changes
- 30–35 fractions; prescription doses 58–70 Gy; daily CBCT images

### Stage 1: Portal Dosimetry Screening

- Transmission portal images acquired every fraction via EPID — no added dose or workflow burden
- Gamma analysis vs. fraction 1 baseline using 3%/2 mm criteria
- Pass threshold: >95% of points with γ<1 and mean γ<0.5
- Processing <10 sec/fraction

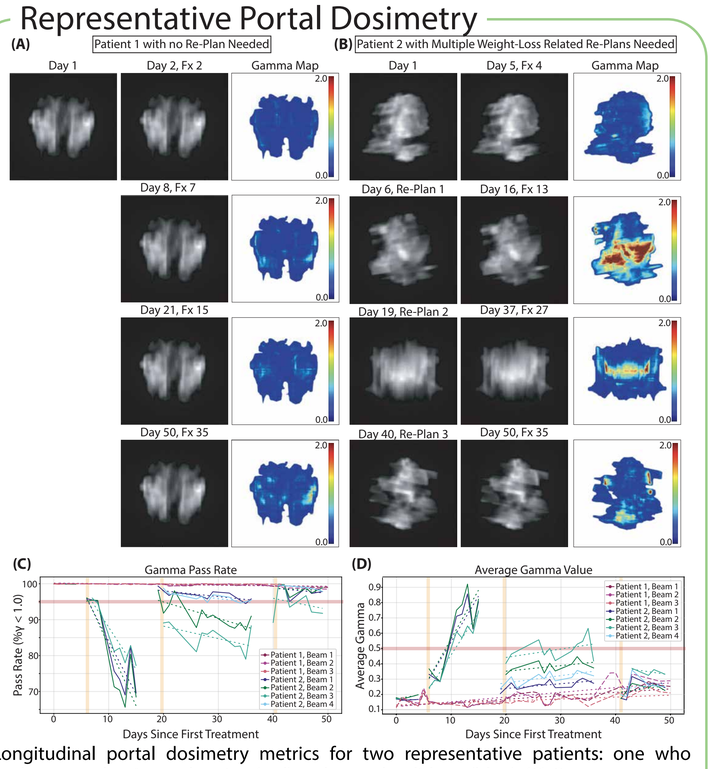
Summary Metrics per Patient

| Avg γ Slope | Pass Rate Slope | Early-Late Pass Rate |
|---|---|---|
| Progressive drift of γ values over the course of treatment | Rate of change of the pass rate (% / fraction) | Pass rate of the first third of fractions vs the last third of fractions |

### Stage 2: Contour Adaptive Assessment

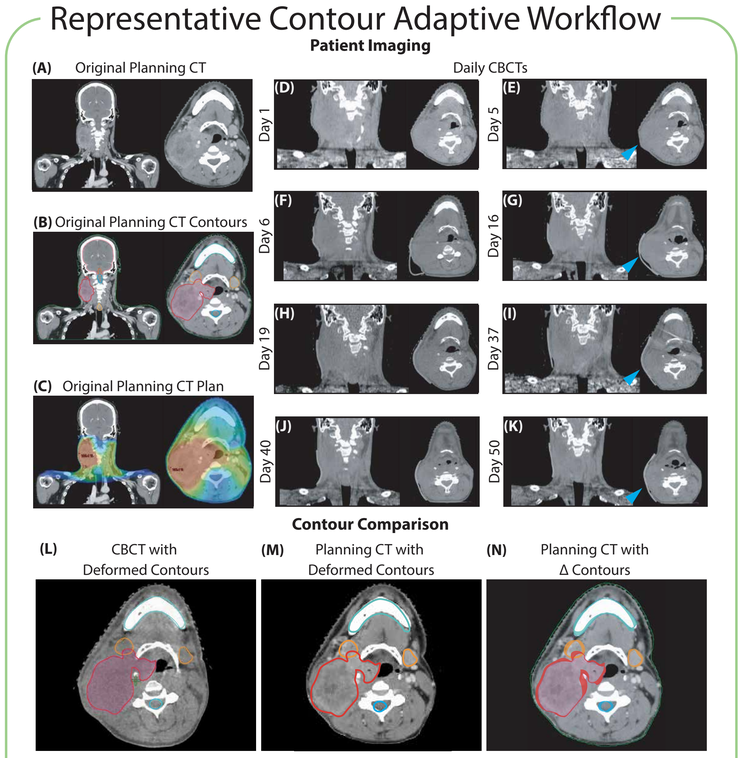
- Rigid + deformable registration of daily CBCT to pCT (Elastix-based); pCT contours propagated onto CBCT
- M.D. review of deformed contours; dose re-sampled
- DVH metrics evaluated: CTV/PTV coverage and OAR doses (parotids, oral cavity, submandibular glands, spinal cord)

### Representative Portal Dosimetry




Longitudinal portal dosimetry metrics for two representative patients: one who underwent adaptive replanning (red) and one who did not (blue). (C) Gamma pass rate and (D) average gamma value plotted as a function of treatment fraction. Yellow highlighted vertical line indicates the fraction at which clinical replanning occurred for the adapted patient and the red highlighted horizontal lines show the value standard used in flagging re-plans

### Representative Contour Adaptive Workflow

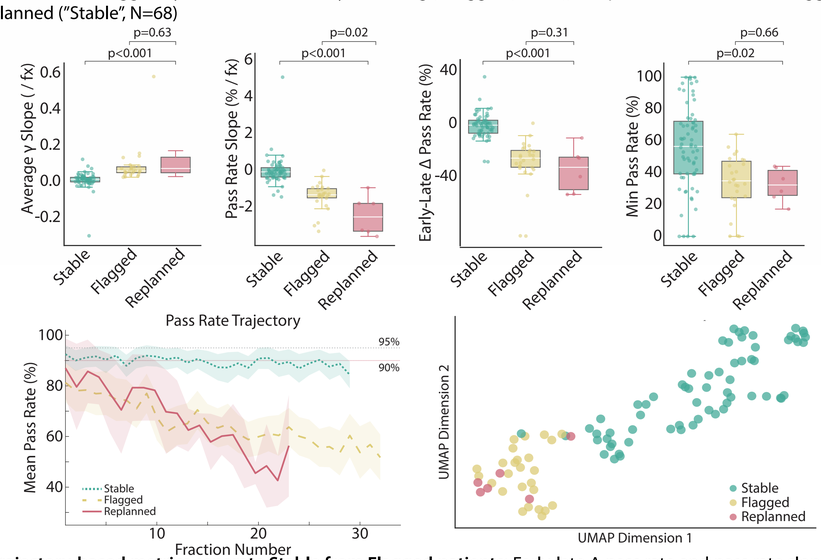



The planning CT (pCT) with contours and dose plan are shown (A-C) with examples of CBCT throughout treatment (D-K). The bottom row shows contours on Day 5 CBCT: with contours propagated from pCT (L), with pCT and propagated contours overlaid (M), and the differences between these contours shaded (N). Arrows in (D-K) show anatomical changes over time.

## RESULTS

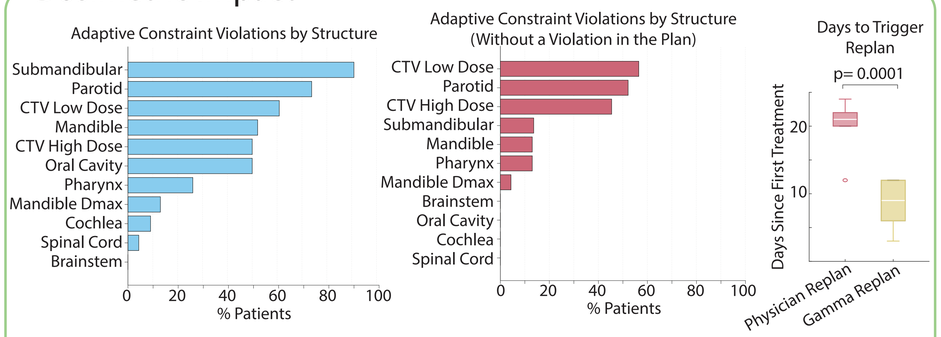
### Gamma Analysis Metrics

Patients were sorted into 3 groups: patients with a replan ("Replanned", N=6), patients who did not have a formal re-plan but were flagged by the Portal Dosimetry Screening ("Flagged", N=26), and patients who were not flagged nor re-planned ("Stable", N=68)




- **Trajectory-based metrics separate Stable from Flagged patients:** Early-late Δ pass rate and pass rate slope show highly significant differences (p<0.001), indicating that declining pass rate trajectory is a key discriminating signal
- **Flagged and Replanned patients are statistically indistinguishable on most individual features:** (p=0.66 for minimum pass rate, p=0.31 for early-late Δ), suggesting comparable anatomical change magnitude between Flagged & Replanned patients
- **Group separation emerges early and widens with treatment progression:** Replanned patients declined from ~80% to below 70% pass rate by fraction 10, while Stable patients remained near the 90% action threshold throughout
- **Uniform Manifold Approximation and Projection (UMAP) projection of the full feature space confirms this pattern**: Stable patients form a distinct cluster while Flagged and Replanned patients co-localize, supporting the hypothesis that a subset of Flagged patients may warrant adaptive consideration

### Dosimetric Impact




- **Salivary glands showed the highest prevalence of adaptive constraint violations**, with submandibular and parotid glands affected in 70–85% of patients on dose recalculation.
- **New violations emerging from adaptive recontouring** were driven primarily by CTV dose coverage degradation (35% of patients) and parotid dose increases (30% of patients), indicating anatomical changes of sufficient magnitude that planning objectives were no longer achievable
- **Portal dosimetry deviation was detected significantly earlier than clinical replanning decisions** (p = 0.0001), with a median of 21 days (IQR: 11–23 days) between portal dosimetry flagging and physician-initiated replan, supporting portal dosimetry as an objective, predictive indicator for adaptive intervention.

### Discussion

- These preliminary results suggest that longitudinal transmission portal dosimetry trends can serve as an effective, low-burden daily screening tool for identifying HN patients whose anatomy is diverging meaningfully from their planning CT
- The temporal concordance between multi-beam gamma threshold violations and clinically triggered replanning events, illustrated in representative cases, provides direct mechanistic support for the link between EPID-detected fluence changes and underlying anatomical evolution such as weight loss and tumor regression
- However, the substantial feature-space overlap between Flagged and Replanned patient groups indicates that portal dosimetry alone cannot fully discriminate which flagged patients truly require replanning, underscoring the value of a tiered approach where contour-adaptive dosimetric assessment is reserved for confirmation in ambiguous cases
- This dual-method framework is attractive because it leverages the near-real-time, near-zero-burden nature of daily EPID acquisition for broad screening, while concentrating the more resource-intensive deformable registration and dose recalculation only on the subset of fractions where anatomical change is most likely

### REFERENCES

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