CBCT Reconstruction Method Affects Deformable Auto-Contour Accuracy of Supraglottic Structures in Head and Neck Cancer

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INTRODUCTION

Accurate delineation of anatomy on cone-beam CT (CBCT) is essential for image-guided and adaptive radiotherapy (RT) in head and neck cancer (HNC), yet CBCT image quality and deformable image registration (DIR) performance remain limiting. While CBCT offers lower image quality than planning CT (pCT), its daily acquisition uniquely tracks anatomical change throughout treatment, and first-fraction CBCT images commonly serve as reference datasets for delta-radiomics and adaptive-therapy workflows.

DIR-based auto-contouring propagates structures from pCT to CBCT, but propagation accuracy varies across DIR algorithms and reconstruction settings, so inaccuracies at this step may carry forward through longitudinal analysis.[1,2,3] This study isolates the effect of CBCT reconstruction method (standard vs. iterative) on supraglottic contour accuracy using two commercial DIR algorithms.

AIM

Evaluate the accuracy of supraglottic contours propagated from pCT to CBCT using two independent DIR-based auto-contouring algorithms across two CBCT reconstruction methods, separating algorithm-driven from reconstruction-driven variability in contour accuracy.

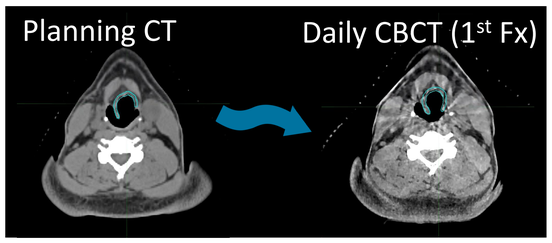


Figure 1. Planning CT (left) and daily CBCT from 1st fraction of the RT (right). The supraglottic volume (in turquoise) was transferred from the planning CT to the 1st treatment day CBCT through deformable registration.

STUDY SNAPSHOT

16 — **HPV+ Oropharyngeal Cancer Patients**
Retrospectively identified from an IRB-approved database; all received IMRT with daily CBCT imaging.

6 — **Geometric & Volumetric Accuracy Metrics**
DSC, ASD, HD95, CMD, RVD, and AVD.

2 — **CBCT Reconstruction Methods Compared**
Standard CBCT (sCBCT) vs. iterative CBCT (iCBCT), 8 reconstructed with each method.

2 — **DIR-Based Auto-Contouring Algorithms**
FF-IBA (free-form, intensity-based) and MR-EBSA (multi-resolution elastic B-spline) compared head-to-head.

METHODS AND MATERIALS

Patient Selection: Sixteen patients with oropharyngeal cancer underwent intensity modulated radiation therapy (IMRT) with daily CBCT, retrospectively analyzed. This retrospective analysis was conducted under institutional review board (IRB) approval.

Contour Propagation: Supraglottic contours delineated on pCT were propagated to first-fraction CBCT using two DIR-based auto-contouring algorithms, selected to represent distinct, commercially available registration approaches:

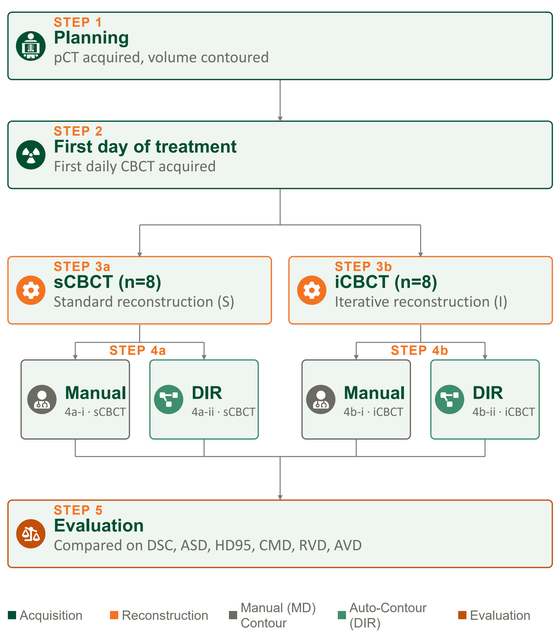
- Free-form, intensity-based algorithm (FF-IBA), MIM ver. 7.4.3
- Multi-resolution elastic B-spline algorithm using mutual information (MR-EBSA), Velocity ver. 4.1

Reference Standard: Propagated contours were compared against reference contours delineated directly on the corresponding CBCT by an expert radiation oncologist, providing a clinically grounded accuracy standard rather than a purely geometric one.

Reconstruction Groups: Eight CBCTs were reconstructed with standard (Ram-Lak filter) CBCT (sCBCT); eight with iterative CBCT (iCBCT).

Accuracy Metrics: Dice similarity coefficient (DSC), average surface distance (ASD), 95th-percentile Hausdorff distance (HD95), center-of-mass displacement (CMD), relative volume difference (RVD), and absolute volume difference (AVD).

WORKFLOW OVERVIEW



RESULTS

- Contour agreement varied between the two deformable auto-contouring algorithms, with FF-IBA consistently outperforming MR-EBSA across both boundary-based and volume-based metrics (Figure 2A–F; Table 1): mean DSC 0.65 ± 0.10 vs. 0.59 ± 0.12; mean ASD 0.74 ± 0.40 mm vs. 0.90 ± 0.71 mm.
- iCBCT reconstruction improved contour accuracy for both algorithms (Table 2). Median DSC rose from 0.55 to 0.69 (MR-EBSA) and 0.63 to 0.71 (FF-IBA), with reduced ASD and HD95. Extreme boundary discrepancies, reflected by HD95 outliers, were also less frequent on iCBCT images for both algorithms, indicating more consistent performance beyond the median case.
- CMD remained comparable between reconstruction methods (median < 3 mm), indicating no systematic geometric bias.
- Volume agreement also improved with iCBCT: reduced variability, fewer extreme RVD outliers, and smaller AVD values.

TABLE 1. ALGORITHM COMPARISON (OVERALL, N=16)

Metric	FF-IBA	MR-EBSA
BOUNDARY-BASED METRICS		
Mean DSC	**0.65 ± 0.10**	0.59 ± 0.12
Mean ASD (mm)	**0.74 ± 0.40**	0.90 ± 0.71
Median HD95 (mm)	**2.53**	2.66
Median CMD (mm)	**1.68**	1.67
VOLUME-BASED METRICS		
Median RVD (%)	24.0	**16.0**
Median AVD (cm³)	0.82	**0.66**

DISCUSSION

This work isolates the effect of CBCT reconstruction method on deformable auto-contour accuracy, identifying reconstruction choice as a critical, often underappreciated, factor influencing both adaptive radiotherapy workflows and quantitative imaging studies (e.g., delta-radiomics) built on early-treatment CBCT. Since first-fraction CBCT commonly serves as the reference dataset for longitudinal analysis, propagation errors introduced at this step may carry forward through the full treatment course. These reconstruction-dependent differences suggest CBCT reconstruction settings should be treated as an explicit variable, not a fixed background parameter, when designing CBCT-based delta-radiomics or adaptive-therapy pipelines. Because many institutions default to a single standard reconstruction protocol for daily CBCT, the accuracy gains observed with iCBCT point to a low-cost, workflow-compatible opportunity to improve auto-contouring fidelity without changing DIR software or clinical hardware.[4]

TABLE 2. MEDIAN CHANGE: sCBCT → iCBCT (N=8 EACH)

Metric	MR-EBSA	FF-IBA
BOUNDARY-BASED METRICS		
Median DSC	**0.55 → 0.69**	**0.63 → 0.71**
Median ASD (mm)	**0.82 → 0.55**	**0.66 → 0.52**
Median HD95 (mm)	**2.98 → 2.14**	**2.63 → 2.30**
Median CMD (mm)	2.06 → 1.00	1.59 → 1.93
VOLUME-BASED METRICS		
Median RVD (%)	**33.4 → 8.4**	**44.7 → 17.0**
Median AVD (cm³)	**1.04 → 0.43**	**1.48 → 0.50**

RESULTS — CONTOUR ACCURACY BY RECONSTRUCTION METHOD

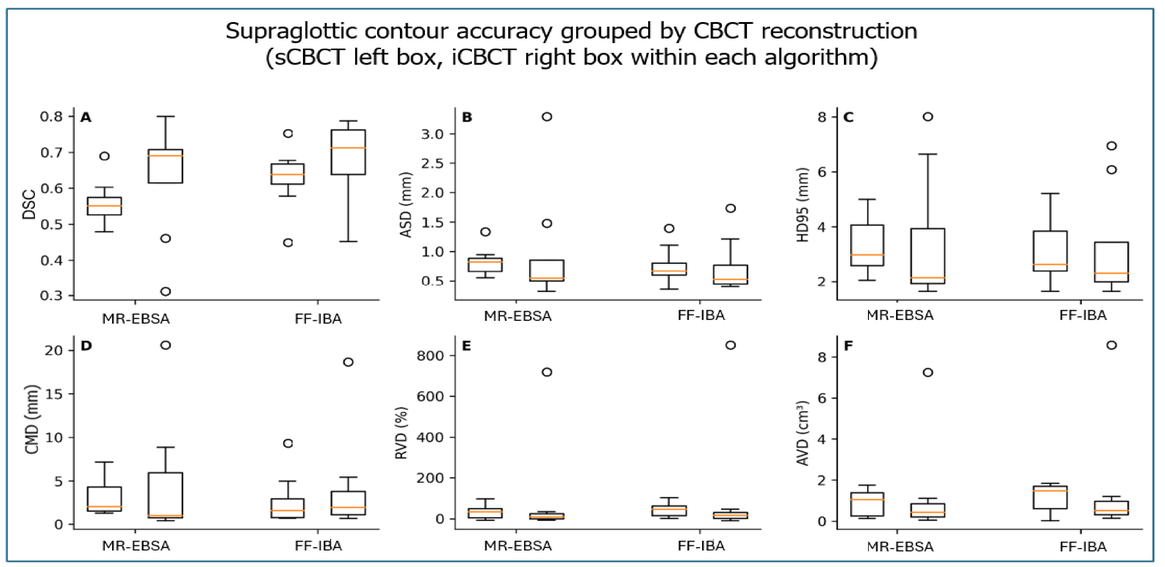


Figure 2. Supraglottic contour accuracy grouped by CBCT reconstruction method for two DIR algorithms (MR-EBSA, FF-IBA): Dice similarity coefficient (DSC) (A), average surface distance (ASD) (B), 95th-percentile Hausdorff distance (HD95) (C), center-of-mass displacement (CMD) (D), relative volume difference (RVD) (E), and absolute volume difference (AVD) (F). Iterative CBCT (iCBCT, right box within each pair) improves contour accuracy across metrics for both algorithms vs. standard CBCT (sCBCT, left box).

CONCLUSIONS

Supraglottic contour accuracy from deformable propagation (pCT → CBCT) is influenced by both DIR algorithm choice and CBCT reconstruction method. iCBCT reconstruction improves boundary agreement and volume consistency without introducing systematic geometric bias. These findings support treating CBCT reconstruction method as a deliberate design parameter, alongside DIR algorithm selection, when building CBCT-based auto-contouring or delta-radiomics workflows for HNC. Findings are based on a retrospective, single-institution cohort of 16 patients and a single anatomic structure (supraglottis); validation in larger, multi-institutional cohorts and additional head and neck subsites is warranted.

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