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Topic (read-only)

Physics: Inter-fraction motion management and daily adaptive radiotherapy

Keywords (read-only)

Synthetic-CT, adaptive, head and neck

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Abstract title (read-only)

Diffusion-based synthetic-CT generation from head and neck CBCT

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Purpose/Objective (read-only)

Cone-beam CT (CBCT) imaging is routinely used in radiation therapy for patient positioning; however, its broader clinical application is constrained by suboptimal image quality, spatial resolution, and field of view. Expanding CBCT beyond setup verification could significantly advance adaptive radiotherapy, provided image fidelity is enhanced to enable accurate organ-at-risk delineation, dose calculation, and treatment replanning. This study presents and clinically evaluates an AI–based method that generates synthetic-CTs (sCTs) from CBCT images. The proposed solution mitigates key technical limitations of CBCT and demonstrates its potential to fully exploit CBCT imaging for adaptive radiotherapy in head and neck cancer management.

Material/Methods (read-only)

Training a 3D multimodal translation model for medical imaging presents several challenges, including the computational burden of volumetric data, the scarcity of high-quality paired datasets, and the need to preserve quantitative accuracy for clinical use. To address these, a 3D latent diffusion model was developed. Its variational autoencoder (VAE) component provides strong compression while maintaining high reconstruction fidelity and computational efficiency. The diffusion model was first trained in an unsupervised manner on unpaired data, then fine-

tuning with 306 head and neck cancer patients (4414 paired datasets).

An independent cohort of 20 head and neck cancer patients treated across three European cancer centres was used for clinical evaluation. Planning-CTs were deformably registered to CBCTs (wCTs) to account for anatomical variations and positioning discrepancies. Treatment plans were re-optimised and recalculated on wCTs and sCTs for dosimetric comparison.

Results (read-only)

Median relative differences in DVH parameters for target volumes between sCTs and wCTs were minimal (0.16–0.35% - Table 1), with the largest for D98% (0.35%) and the smallest for Dmean (0.16%). Median gamma pass rates were 99.75% (2%/2 mm) and 99.94% (3%/3 mm) at a 1% low-dose threshold (Table 2), confirming excellent dosimetric agreement.

Structure	DVH parameter	Median relative difference (%)
Target volumes	Dmax [Gy]	0.33
	Dmean [Gy]	0.16
	D2% [Gy]	0.24
	D5% [Gy]	0.25
	D50% [Gy]	0.19
	D95% [Gy]	0.20
	D98% [Gy]	0.35

Gamma index	2%/2mm			3%/3mm		
Low dose threshold	1%	10%	20%	1%	10%	20%
Median	99.75	99.48	99.35	99.94	99.89	99.88

Conclusion (read-only)

This study demonstrates the feasibility and dosimetric accuracy of AI-generated sCTs from CBCT images in head and neck cancer radiotherapy. The proposed method enables high-fidelity, quantitative image generation, supporting its integration into adaptive workflows for organ-at-risk delineation, dose simulation, and treatment replanning to enhance personalised and efficient radiotherapy.

Conflict of Interest Disclosure (read-only)

- (selected) I do not have a Conflict of Interest to disclose.
- I do have a Conflict of Interest to disclose.

Permission to publish (required)