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Topic (read-only)

Physics: Inter-fraction motion management and daily adaptive radiotherapy

Keywords (read-only)

Synthetic-CT, Adaptive, Breast

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Abstract title (read-only)

Diffusion-based synthetic-CT generation from breast CBCT

Clinical affairs, TheraPanacea, Paris, France

Audrey Duran a.duran@therapanacea.com
AI engineering, TheraPanacea, Paris, France

Quentin Spinat q.spinat@therapanacea.com
AI engineering, TheraPanacea, Paris, France

Pierre Olléon p.olleon@therapanacea.com
AI engineering, TheraPanacea, Paris, France

Sami Romdhani s.romdhani@therapanacea.com
AI engineering, TheraPanacea, Paris, France

Nikolaos Paragyios (Presenting) n.paragios@therapanacea.com
CEO, TheraPanacea, Paris, France

Pauline Maury pauline.maury@gustaveroussy.fr
Department of radiaition oncology, Institut Gustave Roussy, Villejuif, France

Pascal Fenoglietto pascal.fenoglietto@icm.unicancer.fr
Department of radiation oncology, Institut du Cancer de Montpellier, Montpellier, France

Purpose/Objective (read-only)

Cone-beam CT (CBCT) imaging is routinely employed in radiation therapy for patient positioning, but its limited image quality, spatial resolution, and field of view restrict its broader clinical use. Extending its role beyond positioning could accelerate the adoption of adaptive radiotherapy. To achieve this, improvements enabling organ-at-risk delineation, dose calculation, and treatment replanning are essential. This study clinically evaluates an AI–based solution that generates synthetic-CTs (sCTs) from CBCT images, addressing major technical constraints and demonstrating the potential to fully exploit CBCT for adaptive radiotherapy in breast cancer management.

Material/Methods (read-only)

.Training a 3D multimodal translation model for medical imaging presents several challenges, including the large computational burden of volumetric data, the scarcity of high-quality paired datasets, and the need to preserve quantitative fidelity for clinical use. To overcome these, a 3D latent diffusion model was developed. Its variational autoencoder (VAE) component achieves strong compression with high reconstruction quality and computational efficiency. The diffusion model was first trained in an unsupervised manner on unpaired data, then fine-tuned for cross-modality translation using limited paired samples. A ControlNet-based conditioning strategy was employed to achieve anatomically consistent and quantitatively reliable image synthesis. The unsupervised model was trained on approximately 34000 CT scans (50% pelvis, 37.5% head and neck, 12.5% thorax) to ensure anatomical diversity, followed by fine-tuning with 248 breast cancer patients (1126 paired datasets).

Results (read-only)

Median relative differences in DVH parameters for target volumes between sCTs and wCTs were minimal (0.09–0.19% - Table 1), with the largest difference observed for D98% (0.19%). Median gamma pass rates reached 99.74% (2%/2mm) and 99.96% (3%/3mm) with a 1% low-dose threshold (Table 2), confirming excellent dosimetric agreement.

Structure	DVH parameter	Median relative difference (%)
Target volumes	Dmax [Gy]	0.16
	Dmean [Gy]	0.09
	D2% [Gy]	0.10
	D5% [Gy]	0.10
	D50% [Gy]	0.10
	D95% [Gy]	0.17
	D98% [Gy]	0.19

Gamma index	2%/2mm			3%/3mm		
Low dose threshold	1%	10%	20%	1%	10%	20%
Median	99.74	99.40	99.12	99.96	99.89	99.86

Conclusion (read-only)

This study demonstrates the feasibility and accuracy of AI-based CBCT-to-CT conversion for adaptive breast radiotherapy. The resulting sCTs provide dosimetric precision comparable to conventional CTs, supporting their integration into a comprehensive adaptive workflow including organ-at-risk delineation, dose simulation, and replanning to enhance personalised and efficient radiotherapy.

Conflict of Interest Disclosure (read-only)

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- ( ) I do have a Conflict of Interest to disclose.

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