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Self-Supervised GAN Based Synthetic CT Generation From Thorax CBCT

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Purpose/Objective:

Cone-beam CT (CBCT) plays an important role in radiation therapy, primarily focusing on patient positioning due to its limited quality, resolution, and field of view. Expanding the use of CBCT beyond patient positioning has the potential to facilitate the widespread implementation of adaptive treatment. Achieving this requires significant enhancements in signal quality and field of view, enabling comprehensive tasks such as organ-at-risk (OAR) annotation, full-scale dose simulation, and replanning. This study introduces and clinically assesses an artificial intelligence-based synthetic-CTs (sCT) as a proposed solution to address these challenges, aiming to unleash the complete potential of CBCT for adaptive radiotherapy in the context of thoracic cancer care.

Material/Methods:

Training an AI model to generate CT from CBCT is challenging due to the inherent difficulty in achieving alignment between the two. To overcome this, we employed a patented CBCT simulation method, generating a synthetic version by introducing noise and removing projections from corresponding CT instead of relying on imprecise alignments. The AI model was trained to predict the original CT from this simulated CBCT. Subsequently, a GAN was trained with real CBCTs to ensure that the synthetic CTs produced were indistinguishable from actual CTs. The training cohort encompassed 484 planning CTs and 324 CBCTs.

Given that the field of view (FoV) of a CBCT is smaller than that of a planning CT, the synthetic CT (sCT) needed to be enlarged in the X, Y and Z directions to facilitate OAR segmentation and dose computation.

For the evaluation, a retrospective cohort of 10 patients with thoracic cancer, treated at two European cancer care excellence centers were selected. Deformable registration was employed to align planning CTs with CBCTs for each patient, accounting for any changes in body structure and positioning. Treatment plans were optimized based on the warped CT (wCT) and recalculated on the sCTs for thorough image and dosimetric assessments. The comparison between wCTs and synthetic CTs was based on a) DVH-parameters (D2%, D50%, D95%, D98%, and Dmean) for the PTV, and b) dose distributions, evaluated against global gamma criteria (2%/2mm and 3%/3mm).

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Results:

Table 1 exhibits the comparative outcomes regarding variations in DVH between the dose computed on the extended FoV sCTs generated from the CBCTs and the dose computed on the warped CTs. The DVH differences are portrayed through the median and mean relative differences, alongside the minimum and maximum values for seven DVH indicators: Dmean, Dmax, D98%, D95%, D50%, D5%, and D2% for PTV. The most significant disparity was observed for the Dmax parameter (0.56%), while the lowest disparity was noted for the D5% parameter (0.25%). The distinctions in gamma pass rate, indicated by the median values, were 100.00%, 99.97%, 99.96%, and 100.00%, 100.00%, and 100.00% for 0%, 10%, and 20% cut-off dose for 2%/2mm and 3%/3mm, respectively.

Structure	DVH parameter	Median relative dose difference with wCT (%)	Mean relative dose difference with wCT (%)	Minimum relative dose difference with wCT (%)	Maximum relative dose difference with wCT (%)
PTV	Dmean% [Gy]	0.29	0.40	0.04	1.19
	Dmax% [Gy]	0.56	0.85	0.16	3.03
	D98% [Gy]	0.35	0.44	0.06	1.38
	D95% [Gy]	0.45	0.52	0.10	1.57
	D50% [Gy]	0.28	0.44	0.03	1.39
	D5% [Gy]	0.25	0.52	0.01	2.01
	D2% [Gy]	0.26	0.57	0.00	2.14

Table 1: Overall dosimetric results comparing synthetic CTs and warped CTs

Conclusion:

The proposed CNN model trained to predict RT doses was successfully tested for treatments of prostate cancers. The DVHs obtained on the predicted doses were on par with the clinical ones. These results can further be used as input of a knowledge transfer system such as dose mimicking of DVH constraints extraction.