

Synthetic CT generation technology for prostate cancer radiotherapy based on neighbourhood attention-enhanced generative adversarial network

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Cone beam computed tomography (CBCT), a key tool in image-guided radiotherapy, is limited in direct dose calculation for adaptive radiotherapy due to inherent issues such as scattering noise, low contrast, and Hounsfield unit (HU) value distortion. The present study proposes a neighbourhood attention-enhanced generative adversarial network (NA-EGAN) to achieve high-precision conversion of CBCT to synthetic computed tomography (sCT). By systematically comparing the performance of four models (U-Net, cycleGAN, cGAN, and NA-EGAN), we validate the clinical value of NA-EGAN in prostate cancer radiotherapy. Based on a dataset of CBCT and Planning CT (pCT) images from 78 prostate cancer patients, the data were divided into training, testing, and validation sets at a ratio of 63:10:5. NA-EGAN integrates multi-channel input and introduces a self-attention mechanism: channel attention dynamically calibrates feature weights, while spatial attention focuses on dose sensitive regions—significantly enhancing the perception of image boundaries and the anatomical consistency of HU values. Additionally, geometric perception data augmentation (elastic deformation and 3D rotation) was applied to improve the model's robustness to anatomical variations. Finally, dynamic memory-mapped loading technology was used to enhance the efficiency of large-scale data processing. Experimental results showed that NA-EGAN achieved the best performance in global image quality assessment: the mean absolute error (MAE) was reduced to 6.68 ± 0.92 HU, the peak signal to noise ratio (PSNR) reached 56.34 dB, the structural similarity index (SSIM) increased to 96%, and all dice similarity coefficients (DSC) exceeded 0.97. Dosimetric evaluation indicated that the sCT generated by NA-EGAN had a γ pass rate (2%/2mm) of 99.50%. The single-fraction target doses D_{95} and D_{mean} were 1.92 Gy and 2.03 Gy, respectively, with no significant difference compared to pCT, verifying its clinical equivalence. The study shows that NA-EGAN

achieves high-fidelity reconstruction of CBCT images through neighbourhood feature fusion and attention-guided mechanisms. The generated sCT can fully replace pCT in terms of dose calculation accuracy, providing a reliable technical solution for the online dynamic optimisation of adaptive radiotherapy. The model's memory optimisation strategy and geometric enhancement method offer innovative insights for the engineering application of medical image reconstruction, with significant potential for clinical translation.

Keywords: Image verification, machine learning, multi-channel, prostate cancer, radiation therapy, synthetic CT

ACCORDING to the GLOBOCAN 2020 global cancer database, the number of new cases and deaths from prostate cancer in China accounts for 8.2% and 13.6% of the global totals, respectively¹. External beam radiotherapy (EBRT) is one of the effective treatment options for prostate cancer. The Chinese Society of Clinical Oncology (CSCO) Prostate Cancer Diagnosis and Treatment Guidelines 2022 (ref. 2) recommend 74–80 Gy of image-guided conventional fractionated intensity-modulated radiotherapy. For patients with very low-risk prostate cancer, radiotherapy can achieve a curative effect. During radiotherapy, changes in anatomical structures may reduce target volume coverage and increase radiation dose to normal tissues, thereby affecting treatment efficacy³. Therefore, image guidance before each fraction ensures the alignment of the irradiation field with the tumour. In adaptive radiotherapy, cone beam computed tomography (CBCT) is used to correct the target position and adjust the dose in real time⁴. However, CBCT images exhibit large deviations in HU values relative to CT images and excessive noise, making them unsuitable for direct dose calculation⁵.

To overcome the inherent limitations of CBCT, such as scatter artefacts, noise, and unreliable Hounsfield (HU) values for direct dose calculation, significant research efforts have focused on generating synthetic computed

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