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Comparison of generative adversarial networks trained in paired and unpaired fashion for MR-based synthetic CT generation towards MR-only radiotherapy in the abdomen

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Purpose
The aim of this study is to compare deep learning (DL) approaches trained on co-registered image pairs (paired data) and unpaired data requiring only images from each modality. The generation of synthetic CT (sCT) images from magnetic resonance (MR) images acquired with a TrueFISP sequence at a 0.35T hybrid MR-Linac is investigated along with their application for quality assurance (QA).

Methods
A retrospective analysis for 76 patients with a tumour in the abdomen treated at our institution was carried out. First, the influence of generative adversarial network (GAN) architectures trained in paired (Pix2pix) and unpaired fashion (CycleGAN; CUT) were assessed. Second, diverse pre-processing routines (N4 bias field correction; Nyul and novel N-Peaks intensity normalisations) were evaluated. Finally, two input-output network channels configurations (2D, pseudo3D) were compared. Both image similarity metrics and dose-volume histogram (DVH) indicators were used to assess the quality of the generated sCT.

Results
The mean absolute errors (mean ± SD) for best performing configurations are 71.0±20 HU for Pix2pix (Nyul, pseudo3D), 73.4±21 HU for CycleGAN (Nyul, 2D) and 84.5 ±19 HU for CUT (N4 and N-Peaks, 2D). Importantly, trained in unpaired fashion CycleGAN and CUT excel beyond Pix2pix and deformable registration methods in the air pockets reproduction. Regarding the DVH indicators, high correspondence in dose distribution is observed, with mean dose discrepancies below 1% for the planning tumour volume indicators of all models and Dmean equals to 0.33%, 0.32% and 0.40% for Pix2pix, CycleGAN and CUT.

Conclusion
Our study shows that unpaired-trained GANs achieve comparable performance to models requiring perfectly aligned image pairs, essential in the context of scarce clinical data. It also demonstrates that the application of unpaired-trained GANs affects positively the sCT quality for the abdominal region, characterised by significant differences in the shape and location of non-rigid organs and air pockets. The optimisation of various training configuration allows our models to outperform the current state-of-the-art, revealing their potential for clinical application and further implementation of QA procedures for MR-only radiotherapy.

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