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PAPER

Dose evaluation of fast synthetic-CT generation using a generative adversarial network for general pelvis MR-only radiotherapy

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Abstract

To enable magnetic resonance (MR)-only radiotherapy and facilitate modelling of radiation attenuation in humans, synthetic CT (sCT) images need to be generated. Considering the application of MR-guided radiotherapy and online adaptive replanning, sCT generation should occur within minutes. This work aims at assessing whether an existing deep learning network can rapidly generate sCT images for accurate MR-based dose calculations in the entire pelvis.

A study was conducted on data of 91 patients with prostate (59), rectal (18) and cervical (14) cancer who underwent external beam radiotherapy acquiring both CT and MRI for patients' simulation. Dixon reconstructed water, fat and in-phase images obtained from a conventional dual gradient-recalled echo sequence were used to generate sCT images. A conditional generative adversarial network (cGAN) was trained in a paired fashion on 2D transverse slices of 32 prostate cancer patients. The trained network was tested on the remaining patients to generate sCT images. For 30 patients in the test set, dose recalculations of the clinical plan were performed on sCT images. Dose distributions were evaluated comparing voxel-based dose differences, gamma and dose-volume histogram (DVH) analysis.

The sCT generation required 5.6 s and 21 s for a single patient volume on a GPU and CPU, respectively. On average, sCT images resulted in a higher dose to the target of maximum 0.3%. The average gamma pass rates using the 3%, 3 mm and 2%, 2 mm criteria were above 97 and 91%, respectively, for all volumes of interests considered. All DVH points calculated on sCT differed less than $\pm 2.5\%$ from the corresponding points on CT.

Results suggest that accurate MR-based dose calculation using sCT images generated with a cGAN trained on prostate cancer patients is feasible for the entire pelvis. The sCT generation was sufficiently fast for integration in an MR-guided radiotherapy workflow.

1. Introduction

'Magnetic resonance (MR)-only' radiotherapy refers to a radiotherapy workflow in which patient simulation and dose calculation are performed using only MR images. This workflow has been proposed to exploit the soft tissue contrast offered by magnetic resonance imaging (MRI) without recurring to inter-modality registration and thus reducing possible systematic errors in target definition (Nyholm *et al* 2009). Also, MR-only radiotherapy offers practical and logistical advantages reducing the overall treatment cost (Devic 2012), workload (Karlsson *et al* 2009) and patient exposure to ionising radiation (Schmidt and Payne 2015). In addition, MR-only is of interest considering the advent of MR-guided radiotherapy (MRgRT) systems