Accuracy of Synthetic CT Images Generated using Cycle GAN

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INTRODUCTION

Treatment planning in modern radiation therapy involves using both computed tomography (CT) and magnetic resonance imaging (MRI) for many disease sites in patients. Although CT images provide electron density values needed for treatment planning, MRI images provide superior soft tissue contrast to delineate tumors and soft tissues. several challenges must be overcome before introducing MRI-only planning into the clinic, including developing robust methods to accurately generate synthetic CT images from MRI images. This study assessed the dosimetric accuracy of synthetic CT images generated from magnetic resonance imaging (MRI) data for focal brain radiation therapy, using a cycle generative adversarial network approach.

METHODS

We conducted a study in 77 patients with brain tumors who had undergone both MRI and computed tomography (CT) imaging as part of their simulation for external beam treatment planning. We designed a CycleGAN network to generate synthetic CT images from MRI images. The model was trained using all MRI slices with corresponding CT slices from each training subject's MRI/CT pair. Both images were imported into the treatment planning system (Eclipse v15.0 Varian medial System). Then, the synthetic CT images rigidly aligned to the CT images for dose comparison using Eclipse software. Targets and OARs including left and right eye, optic nerves, optic chiasm, and brainstem were contoured on CT images and reviewed by the radiation oncologist. In the next step, CT contours were transferred to the registered synthetic CT images, and the optimized VMAT plan was transferred from CT to the synthetic CT images. Dose was calculated on synthetic CT images using the transferred plan from the original CT images. In addition, we optimized the plan for CT and synthetic CT separately and measure mean dose value in planning target volume (PTV) and OARs

DATASETS

CT and MRI images from patients who had undergone brain tumor radiotherapy were analyzed. Tumor sizes varied between 1.1 and 42.4 cm^3. The images were collected at the University of Texas Southwestern Medical Center (UTSW) as part of the standard treatment protocol. Patients underwent both CT (Phillips Big Bore scanner, Royal Philips Electronics, Eindhoven, The Netherlands) and MRI scanner for radiotherapy treatment planning. All CT images were acquired in the Department of Radiation Oncology using a 16-slice CT, 120 kV, exposure time= 900 ms and 180 mA. Images were acquired with a 512x512 matrix and 1.5 mm slice thickness (voxel size 0.68mm×0.68mm×1.50mm). Because this is a retrospective study and MRI scans were performed in the Department of Radiology, image acquisition used different vendors. However, the MRI images were acquired using a 1.5T magnetic field strength and a post-gadolinium 2D T_1-weighted spin echo sequence with TE/TR = 15/3500 ms, a 512 x 512 matrix and average voxel size 0.65 x 0.65x1.5 mm^3. The range of pixel size of MRI data was 0.51 x 0.51mm^2 - 0.88 x 0.88mm^2. To train the model, the MRI images were resampled to the same voxel size of CT images. In addition, the synthetic CT have the same voxel value as CT images (0.68 x 0.68x1.5 mm^3)

RESULTS

Organ	D_X	Patient Number											
		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	Mean ± SD
PTV	D_{95}	1.1	0.2	0.5	0.2	0.1	0.2	0.9	0.5	0.2	0.1	0.9	0.4 ± 0.4
	D_5	0.7	0.9	0.1	0.4	0.1	0.1	0.8	0.1	0.5	1.1	0.6	0.4 ± 0.4
	D_{mean}	0.0	0.2	0.3	0.2	0.0	0.2	0.9	0.1	0.1	0.6	0.3	0.3 ± 0.3
Brainstem	D_2	5.1	0.2	NA	0	0.6	0.7	1.0	0.4	0.8	0.2	1.1	1.0 ± 1.5
	D_{mean}	1.1	1.0	NA	0	0.9	0.1	0.6	0.4	0.0	0.0	0.1	0.4 ± 0.4
Optic chiasm	D_2	0.1	0.8	1.2	0	0.0	0	2.4	NA	0.2	5.2	NA	1.1 ± 1.7
	D_{mean}	1.5	0.2	0.9	0	0.2	0	1.5	NA	0.6	6.0	NA	1.2 ± 1.9
LON	D_2	2.4	0.0	3.2	0	0.5	0	2.5	0.3	0.4	0.4	NA	1.0 ± 1.2
	D_{mean}	1.2	0.0	2.3	0	0.1	0	0.5	0.7	0.8	1.9	NA	0.7 ± 0.8
RON	D_2	6.9	0.8	0.4	0	4.1	0	1.4	NA	0.5	NA	NA	1.8 ± 2.5
	D_{mean}	1.5	0.2	0.0	0	1.2	0	0.0	NA	0.1	NA	NA	0.4 ± 0.6

Table 1. Absolute differences between relevant DVH metrics on the CT and SCT for the 11 test patients, expressed as percentage (%) of the prescription dose (60 Gy). The last two columns contain the mean over all patients and its standard deviation (SD). NA: Not Applicable, when the organ was not contoured for a specific patient. LON/RON: Left/Right Optic Nerve.

CONCLUSIONS

The proposed method provided an accurate and reproducible synthetic CT images using a GAN model, increasing efficiency, accuracy, and precision in clinical workflow. The computational time in our study was about 1 second per patient for generating synthetic CT image and training time was 33 hours using a NVIDIA Tesla K80 dual-GPU graphic card. The MI loss function enables the model to use un-paired data for generating synthetic CT images. Future work is to develop 3D GAN models with larger training datasets for generating synthetic CT images to be used in MRI-only radiotherapy.

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