Generation of synthetic CT from weakly paired MR-CT images using CycleGAN for abdominal MR-guided radiotherapy

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Purpose:
One major issue in MR-guided radiotherapy (MRgRT) is the assignment of electron density to MRI scans for dose calculation. A common strategy consists of applying additional CT imaging and registration between MR and CT images to generate deformed CT (dCT). However, there is risk of registration inaccuracy as a result the discrepancies in patient position, anatomical changes between scans. In order to overcome these difficulties, many attemps have been made to generate synthetic CT (sCT) from MRI, especially using deep learning (DL)-based methods. However, few studies have applied a DL-based approach to the abdomen due to spatial misalignment. Therefore, in this study, we propose sCT generation algorithm using Cycle-consistent generative adversarial network (cycleGAN) and compare it with the U-net based results.

Methods:
Thirty patients data who underwent MRgRT were retrospectively considered. All patient MRI scan using 0.35T ViewRay MRIdian system was obtained after CT scan using Philips CT scanner. We utilized two different DL-based methods, U-net and CycleGAN, to generate a sCT image from an weakly paired MR and CT dateset. The accuracy of the sCT was evaluated by calculating the mean abolute error (MAE), root mean square error (RMSE), and peak signal-to-noise ratio (pSNR) compared with dCT. For dosimetric evaluation, the ViewRay treatment plannign system as employed for treatment planning. With the sCT images, dose distribution calculated under the identical conditions as the dCT treatment plan. To examine the difference between sCT and dCT calculated doses, we performed gamma index evaluation.

Results:
Generating sCT using CycleGAN led to higher quality than using U-net for all geometric and dosimetric indices. The MAE, RMSE, and pSNR obtained with CycleGAN and U-net were 58.8±4.4 HU, 113.0±9.3 HU, 26.3±0.7 dB, and 144.9±55.4 HU, 171.6±22.9 HU, 22.9±3.1 dB, respectively. Regarding the dosimetry, 2%,2mm gamma indices of 99.4±0.7% and 86.9±13.0% were obtained with CycleGAN and U-net, respectively.

Conclusions:
In this study, we proposed a CyclcGAN network to generate sCT and compared U-net network for the abdominal MRgRT. The result suggest that CycleGAN, an unsupervised learning method, is more robust to MR and CT spatial inconsistency than U-net. The accurate dose caculation results imply that it can be potentially used in clinical practice in abdomen MRgRT.

Keywords:
Synthetic CT, MR-guided radiotherapy, Generative adversarial network, U-net