Title: Synthetic computed tomography (CT) image from cone-beam computed tomography (CBCT) using Perceptual Loss for eliminating cone-beam artifacts

Purpose:
Cone-beam computed tomography (CBCT) is widely used for image-guided radiation therapy (IGRT). The application of CBCT can be extended to adaptive radiation therapy (ART) for dose accumulation and re-planning, which are currently limited in accuracy due to degraded image quality from cone-beam artifacts. Thus, this work presents an advanced deep learning (DL) algorithm for generating synthetic CT from CBCT by incorporating perceptual loss.

Methods:
The patient cohort for the DL model consisted of 43 scans with paired CBCT and CT images. The dataset was split into 35, 3, and 5 patients for train-set, valid-set, and test-set, respectively. We utilized a 2-dimensional FC-DenseNet as the DL architecture to eliminate the cone-beam artifacts of CBCT. CT slices were deformable registered and resampled to CBCT using MIM software (Mim Software Inc., Cleveland, OH, USA) and MATLAB (The MathWorks Inc., Natick, MA, USA), respectively. With L1-loss only, we found that details in bone structure disappeared in synthetic CT generation. To enhance the translating performance, the perceptual loss besides L1-loss was newly applied. Data augmentations (horizontal/vertical flip, random rotation, and random blur) were conducted to increase the data size for training. The similarity metric to assess the trained networks employed structural similarity index (SSIM) and mean absolute error (MAE).

Results:
5 patients with paired CBCT/CT images were randomly selected to validate our trained networks. Two networks with L1-loss and (perceptual loss+L1-loss) resulted in similar MAEs (0.050 and 0.044). The L1-loss based network may well produce slightly lower MAE as the L1-loss emphasizes compressing MAE. Contrarily, in SSIM, our proposed network with additional perceptual loss outperformed that with L1-loss only (0.756 to 0.824). It implies that the perceptual loss substantially contributed to improving the similarity of synthetic CT produced from CBCT to real CT images.

Conclusions:
Our DL model with perceptual loss was demonstrated to promote the performance to eliminate cone-beam artifacts and can preserve the detail of bone structure from CBCT to CT image translation, which can strengthen the usefulness of CBCT in radiotherapy.