

Theme: Physics

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Abstract Title: Deep learning-based real-time 3DCT reconstruction for 4D carbon-ion precision radiotherapy

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Background / Aims:

Real-time volumetric imaging is crucial for the next generation real-time adaptive carbon-ion radiotherapy, both in 3D target volume tracking and real-time treatment plan adjustment during the beam delivery. This study introduced and evaluated a fast real-time 3DCT reconstruction method based on deep learning, aiming at improving the accuracy of carbon-ion radiotherapy for moving tumor targets.

Subjects and Methods:

A patient-specific deep learning network, named DrNet, was developed to extract prior knowledge from 2D dynamic projection image sequences to generate real-time 3DCT images. The innovative framework was based on DenseNet, incorporated global attention mechanism and multi-dimensional feature fusion layers to improve the accuracy and details in the reconstruction of real-time 3DCT images, as shown in Figure 1(a). For DrNet training, 4DCT data including 150 three-dimensional (3D) CT sets were collected from 7 lung cancer patients. And the second set of 4DCT acquired from the same patient at intervals was utilized as the test set. The qualitative and quantitative analyses were conducted on the reconstruction results of the model. Furthermore, 4D carbon-ion dose calculations were performed based on the reconstructed and ground truth 4DCT images, aiming at evaluating the 4D dynamic dose distributions under the free breathing and gating with fast beam rescanning scenarios.

Result:

Compared to the previous method, DrNet demonstrated significantly higher image quality and superior accuracy, with peak signal-to-noise ratio (PSNR) and structural similarity (SSIM) values of 30.286 and 0.948, respectively, as shown in Figure 1(b). The  $\gamma$  passing rate of the 4D dose distributions calculated on the reconstructed and ground truth 4DCT images could reach over 95% as 4~6 times beam rescanning were performed, as shown in Figure 1(c).

Figure 1. (a) The detailed structure of the DrNet network; (b) Examples of the 4DCT images from a patient's test set. The first two rows represent the results generated by ReconNet and DrNet and the last row is the ground truth. Different columns represent 10 different phases in the 4DCT images; (c) The 4D dose distributions for an example case calculated on the reconstructed and ground truth 4DCTs with different beam scanning scenarios.

