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Original article

Evaluation of the pulmonary perfusion generated by deep learning-based enhanced cone beam computed tomography

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ABSTRACT

Objective: To evaluate perfusion images generated by enhanced cone beam computed tomography (CBCT), quantify their correlation with CT-based perfusion images, and analyze the factors that may affect their clinical application.

Methods: Thirty lung cancer patients with CBCT-CT pairs and single-photon emission computed tomography (SPECT) perfusion images were studied. A previously developed Cycle GAN CBCT enhancement model and a 3D CNN CT-to-perfusion model were utilized to generate perfusion images. Both CBCT images and SPECT perfusion images were registered to the corresponding CT images for further process. Registered CBCT images were input into the Cycle GAN model to produce enhanced CBCT (eCBCT) images. Subsequently, the lung mask generated from CBCT was applied to CBCT, eCBCT, CT, and SPECT images, generating $CBCT_{segCBCT}$, $eCBCT_{segCBCT}$, $CT_{segCBCT}$, and $SPECT_{segCBCT}$. Additionally, the CT lung mask was applied to CT and SPECT images for comparison, resulting in CT_{segCT} and $SPECT_{segCT}$. Then all 4 sets of CT images ($CBCT_{segCBCT}$, $eCBCT_{segCBCT}$, $CT_{segCBCT}$, CT_{segCT}) were translated into perfusion images using the 3D CNN network. Evaluation metrics, including Spearman's correlation coefficient *R* and structural similarity index measure (SSIM) for voxel-wise agreement and dice similarity coefficient (DSC) for function-wise agreement, were calculated between the generated perfusion images and their corresponding ground truth SPECT images.

Results: After enhancement, the SSIM between CBCT and CT has increased from 0.804 ± 0.072 to 0.824 ± 0.068, while the peak signal-to-noise ratio (PSNR) increased from 24.16 ± 2.82 to 25.04 ± 2.88. Furthermore, the mean absolute error (MAE) decreased from 47.75 ± 15.95 to 40.13 ± 14.61, showing that the eCBCT has higher voxel-wise agreement with CBCT. For CT-to-perfusion translation, the average Spearman correlation *R* for $CBCT_{segCBCT}$, $eCBCT_{segCBCT}$, and $CT_{segCBCT}$, and CT_{segCT} was 0.64, 0.68, 0.73, 0.76, and the average SSIM was 0.62, 0.78, 0.76, 0.79, respectively. Function-wise evaluation of generated perfusion images showed a moderate agreement with the ground truth and the 4 sets had similar results, with DSC (High function) around 0.62 and DSC (Low function) around 0.69. In general, the order of performance from best to worse is: CT_{segCT}, $CT_{segCBCT}$, $eCBCT_{segCBCT}$, and $CBCT_{segCBCT}$, as expected.

Conclusion: In this study, pulmonary perfusion images were generated from CBCT images, demonstrated the potential application of CBCT-based functional images in functional lung avoidance radiotherapy (FLART). Although reducing noise and artifacts in CBCT images can enhance the accuracy of CT-to-perfusion translation and produce perfusion images with a roughly similar pattern, the incomplete lung regions in CBCT, due to limited fields of view, affect the performance of the CT-based translation model.

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