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Development of deep learning-based C-arm CT/SPECT imaging system for online adaptive brachytherapy

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Adaptive radiation therapy (ART) enables an accurate targeting of tumors by accounting for ongoing changes in the patient's anatomy and/or physiology during the course of treatment. Currently, the ART technique is quickly evolving owing to the development of diverse deep learning methods and their application to medical imaging techniques. Even though the high dose rate brachytherapy technique has been significantly improved, its current state of the art has various limitations in online ART due to the absence of an efficient imaging system and a proper beam delivery verification process. In this study, therefore, we developed a deep learning-based image quality improving technique applicable to a C-arm CT/SPECT imaging procedure for online adaptive brachytherapy. Image dataset of 35 noncontrast pelvis CT studies (˜5000 image series) was acquired from The Cancer Imaging Archive data repository and the limited-angle Cone-beam CT (CBCT) images were generated by mathematically calculating sinograms for voxel phantoms based on these CT images with MatlabTM. With a cycle-consistent generative adversarial network (Cycle-GAN), low-quality CBCT images obtained by a 110° limited-angle rotating C-arm fluoroscopic system were transformed to high-quality diagnostic CT images. The performances of these networks were evaluated by comparing them with CBCT images reconstructed by an iterative reconstruction method and ground truth images. The synthetic CT images were successfully transformed from the low-quality CBCT images considerably reducing the streaking artifacts and preserving anatomical structures. Because of the use of the correlation coefficient loss and shape consistency information to directly enforce the structural similarity between the CBCT and the synthesized image, the Cycle-GAN showed the highest performance when evaluating image qualities with the parameters such as structural similarity, root mean square error, and spatial resolution. In this study, we confirmed the availability of online high-quality CT imaging with the limited-angle rotating C-arm fluoroscopic system by applying the deep learning technique, which enables the image-guided brachytherapy and online adaptive treatment planning.

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