

Purpose: To study how the performance of 4D Cone Beam CT varies with gantry rotation time and the number of phase bins when two different reconstruction methods, Filtered Back-Projection (FBP) and Prior Image Constrained Compressed Sensing (PICCS) are used.

Methods: Numerical simulation studies were performed using a hybrid phantom. The phantom consists of in vivo human subject data and simulated lung cancer tumors with motion. The data acquisitions were simulated at 1, 2, 3, and 4 minutes. After data were sorted into different number of phase bins (5, 10, and 20), 4D CBCT images were reconstructed using FBP and PICCS methods. Motion trajectory of the tumor was then extracted using a free-form deformable registration method. The root mean square error (RMSE) was used to characterize the deviation of motion trajectory from the ground truth.

Results: (1) When gantry rotation time becomes longer, FBP-4DCBCT images show reduced streak artifacts and improved accuracy in extraction of tumor motion profile (RMSE=5.4 mm, 2.5 mm, 1.5 mm, and 0.5 mm for 1, 2, 3, and 4 minutes gantry time respectively, for in-plane motion); (2) PICCS-4DCBCT enables streak-free images starting at 1-minute gantry rotation while FBP-4DCBCT requires more than 4 minutes to achieve the comparable accuracy in motion trajectory (RMSE=0.2 mm for PICCS-4DCBCT at 1-minute gantry rotation and RMSE=0.5 mm for FBP-4DCBCT at 4-minute gantry rotation); (3) For in-plane motion, when the number of phase bins increases, the RMSEs increase for FBP-4DCBCT, while they are much more stable for PICCS-4DCBCT.

Conclusions: (1) To accurately extract tumor motion profiles, the number of phase bins should be more than 10. (2) PICCS-4DCBCT enables accurate extraction of tumor motion profile using 1-minute gantry rotation. In contrast, more than 4 minutes are required for FBP-4DCBCT to achieve acceptable accuracy for extraction of tumor motion profiles.