Purpose: To enhance the image quality of four dimensional cone beam computed tomography (4D-CBCT) of lung cancer patients through using information from the initial planning CT.

Method and Materials: 4D-CBCT is obtained by deforming the planning CT. The estimation of the deformation vector fields (DVF) to deform the planning CT is formulated as an unconstrained optimization problem. The objective function to be minimized is the sum of the squared difference between the forward projection of the deformed planning CT and the measured 4D-CBCT projection. A non-linear conjugate gradient (NLGC) method is used to solve the DVF. As the number of the variables in the DVF is much greater than the number of measurements, the solution to such a highly ill-posed problem is very sensitive to the initial parameters during the optimization process. We propose to estimate the DVF using demons registration between planning CT and 4D-CBCT reconstructed by total variation minimization as the initial parameters in the optimization process. A 4D nonuniform rotational B-spline based cardiac-torso (NCAT) phantom and a patient 4D-CBCT are used to evaluate the algorithm.

Results: Image quality of 4D-CBCT is substantially improved by using the proposed strategy in both NCAT phantom and patient studies. For the NCAT phantom, the relative error within lung in 4D-CBCT reconstructed using the standard FDK from 20 projection views is 43.3%; the relative error is 21.5% in images reconstructed by total variation minimization, and further reduced to 12.5% in images reconstructed using the proposed strategy.

Conclusion: Using the proposed strategy, high quality 4D-CBCT can be obtained by deforming an initial planning CT. Results from the phantom evaluation study demonstrates that 20 projections are sufficient to reconstruct 4D-CBCT of high accuracy.

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