Purpose: To simulate the process of generating fluoroscopic 3D treatment images from 4DCT and measured 2D x-ray projections using a realistic modified XCAT phantom based on measured patient 3D tumor trajectories.

Methods: First, the existing XCAT phantom is adapted to incorporate measured patient lung tumor trajectories. Realistic diaphragm and chest wall motion are automatically generated based on input tumor motion and position, producing synchronized, realistic motion in the phantom. Based on 4DCT generated with the XCAT phantom, we derive patient-specific motion models that are used to generate 3D fluoroscopic images. Patient-specific models are created in two steps: first, the displacement vector fields (DVFs) are obtained through deformable image registration of each phase of 4DCT with respect to a reference image (typically peak-exhale). Each phase is registered to the reference image to obtain (n-1) DVFs. Second, the most salient characteristics in the DVFs are captured in a compact representation through principal component analysis (PCA). Since PCA is a linear decomposition method, all the DVFs can be represented as linear combinations of eigenvectors. Fluoroscopic 3D images are obtained using the projection image to determine optimal weights for the eigenvectors. These weights are determined through iterative optimization of a cost function relating the projection image to the 3D image via the PCA lung motion model and a projection operator. Constructing fluoroscopic 3D images is thus reduced to finding optimal weights for the eigenvectors.

Results: Fluoroscopic 3D treatment images were generated using the modified XCAT phantom. The average relative error of the reconstructed image over 30 sec is 0.0457 HU and the standard deviation is 0.0063.

Conclusions: The XCAT phantom was modified to produce realistic images by incorporating patient tumor trajectories. The modified XCAT phantom can be used to simulate the process of generating fluoroscopic 3D treatment images from 4DCT and 2D x-ray projections.