Purpose:
Vessel and bronchial bifurcations are ubiquitous in the lungs and their motions caused by respiration are detectable in 4D CT and serve as valuable internal fiducial markers for studying and monitoring the respiratory motion patterns of the lungs. Bifurcations also serve as reliable landmarks for validation of deformable registration models. In this work, we report the first systematic investigation of motion patterns of a large collection of lung bifurcations.

Methods:
More than 500 bifurcations are identified automatically on a reference image. Each bifurcation is tracked separately. Trajectory of a bifurcation is defined by a B-spline space curve with 5 control points with imposed cyclic constraints. A metric is defined as the combination of the correlation coefficients from all images with respect to the reference image. It is used to measure how well the image intensities on the trajectory match. Correlation coefficient is employed since it is bounded and straightforward to indicate the reliability of a tracked trajectory. Finally, an optimization strategy based on the L-BFGS method is employed to optimize the metric parameterized by the coordinates of control points. Local extrema, if found, are suppressed by improving the initial conditions by random walks from pair-wise optimizations.

Results:
We successfully tested our method in 5 cases. With automatically detected bifurcations, the tracked trajectories correspond to image intensities of high correlation coefficients. Non-homogeneous and hysteretic motion is clearly observable in all cases. For validation, the tracking error is measured by computing the distance between the tracked and manual bifurcations. On average, the error is within the voxel size in all cases.

Conclusions:
We have shown that our approach can track the motion of the bifurcations in 4D CT images of the lung accurately. It may substitute the invasive fiducial markers as noninvasive counterparts for future real-time volumetric imaging guided radiation therapy.