Purpose:

Respiratory motion may vary significantly from the planning stage to the time of treatment, leading to challenges in motion-based treatment intervention. The purpose of this study was to develop a computational framework allowing for accurate prediction of daily respiratory motion from single 3D daily image under drastic inter-fractional respiratory variations and anatomic changes, by taking advantage of prior knowledge of motion and anatomic relationship.

Methods:

Deformable image registration (DIR) was first performed across planning 4D-CT to obtain a set of displacement vector field (DVF), which were further modeled by Principal Component analysis (PCA) to learn a prior motion model, namely a subspace spanned by principal bases. Subsequently, DIR was employed again across vowels of planning and daily images to calculate the DVF for inter-fractional motion, which was used to spatially map the learned prior motion subspace (principal bases) onto the grid of daily image. Finally, we estimated the component of inter-fractional respiratory variations by linear projection of inter-fractional DVF onto mapped motion subspace. The resultant projections were utilized to compensate the reconstruction of daily respiratory motion. The reconstructed respiratory motion will be useful for various image-guided treatment intervention strategies.

Results:

We applied the proposed framework for the prediction of respiratory motion from single daily CBCT and/or free-breathing conventional CT using patients from a proton protocol undergoing weekly 4D-CT evaluation. The accuracy of our model was visually and quantitatively confirmed by the excellent agreement between predicted contours by our model and physician approved ones. For a case with large tumor shrinkage, a DICE score of 90.2% has been achieved; even for another case with drastic respiratory motion difference (around 2cm) from planning stage, the agreement is also close to 90%.

Conclusions:

We have proposed and validated a novel framework to predict respiratory motion from single 3D daily image.