Purpose: To quantify the movements of non-small cell lung nodules using 4D cone-beam computed tomography (4D-CBCT) that is automatically registered with planning CT, and to develop a mathematical model to predict the motion trajectory. Modeling the tumor motion may reduce the PTV and ultimately increase the therapeutic ratio.

Methods: Absolute coordinates of the lung nodules in 15 patients were quantified for each phase of 4D-CBCT scans using auto-registration methods. Assuming respiration follows an elliptical pattern spatially in the lung, these coordinates were fitted to trigonometric functions in each x-y-z direction. Adjusting for phase dependence, the motion could be compared quantitatively for inter-fractional and intra-patient variations to determine if this model is universally applicable and has predictive value.

Results: Examination of over 36 sets of 4D-CBCT data shows acceptable agreement (< 2mm) with the elliptical model for both individual scans and over the course of treatment. Some inter-fractional variations in amplitude and cycling periods indicate the need to remodel as patients' conditions change. The intra-patient variations are significant and strongly dependent on the patient lung volume and tumor location, thus individual modeling of tumor motion is expected.

Conclusions: The model indicates good agreement and clinical relevance with non-small cell lung nodule motion, and it appears to be potentially relevant over the course of treatment. Most re-acquired 4D-CBCT images inter-fractionally were within the baseline spatial resolution of the auto-registration technique. However, if remodeling is necessary inter-fractionally, this model still has the potential for significant motion margin reduction over the course of treatment.