Lung Tumor Volume Change and Correlation to Initial Size and Motion

Innovation/Impact: We believe that this study is innovative since it explores the dependence of tumor motion on tumor location and therapeutic shrinkage. This information has the potential to have a significant impact on clinical care.

Methods and Materials: Time dependence of the Philips Big Bore™ CT scans was obtained via placement of a bellows around the abdomen and subsequent ten phase reconstruction of the breathing cycle. Lung tumor lesions were contoured on inspiration (0% breathing phase) and exhalation (50% breathing phase) by a board certified radiation oncologist. The Lung window and level was chosen during contouring, to help to establish well defined lesion borders. Setup markers were placed during CT scans in rough proximity to the lesion to be treated. Lesion volume and centroids were determined automatically via treatment planning software (Pinnacle®, 9.0, ADAC Philips).

Results: Tumor Volume Change vs. Initial Volume: Figure 1 shows a plot of initial tumor volume vs. volume change during the course of therapy. As can be seen here, smaller volume tumors generally have more relative shrinkage. A power law fit the data better than an exponential: \( R^2 \) (Pearson Product) = 0.49 vs. 0.16 for the power law vs. the exponential.

Tumor Diaphragm Distance - Motion: Figure 2 shows a plot of diaphragm to lesion distance vs. tumor motion for both the initial scan, and subsequent rescans. As expected, a positive correlation was observed for diaphragm proximity and motion\(^\text{12}\). Little difference is seen between the two (initial and rescans) data sets.

External BB - Motion: As a check, a reference point was determined via the use of external BBs placed near the vicinity of the lesion. Figure 3 shows a screen shot of the reference point, formed by the perpendicular intersection of a left-right line through the lateral BBs, and an anterior-posterior line through an anterior (sternal) placed BB (shown in green). The motion of this reference point demonstrated little variation with respect to breathing phase: average initial and rescans left-right -0.01±0.07 and -0.03±0.05cm respectively, average initial and rescans anterior-posterior 0.03±0.04 and 0.04±0.06cm and average initial and rescans superior inferior 0.00±0.00 and 0.00±0.00cm. This gives confidence that the tumor motion was due to respiration alone.

Tumor Volume Change - Motion: Figure 4 shows a plot of the ratio of the recan superior-inferior motion, to the initial superior-inferior motion vs. volume change. As can be seen in the plot, the tumors with a greater than 40% volume reduction had a ratio close to one with all four values close: ratio=1.07±0.36. The tumors that had less volume change showed a slightly lower corresponding ratio, and significantly greater variation: ratio=0.79±0.76.

Discussion: The small sample size studied makes drawing definite conclusions difficult. However, the correlation of motion with diaphragm proximity along with the lack of motion of the reference point gives a measure of assurance that the data are reproducible. The fact that lesions with more volume change (shrinkage) had more predictable motion change may be due to the fact that normal parenchymal lung also has predictable motion change, and the tumors that approach this state begin to emulate it.

Conclusion: As expected, tumors close to the diaphragm exhibited the maximal amount of motion, and this motion was greatest in the superior-inferior direction. In addition, a reference point formed by perpendicular lines through external markers provides a useful measure of reproducibility. Finally, more data are needed to investigate a potential variation of tumor volume change with predictive motion changes.


\(^{2}\)Sonke and Belderbos, 'Adaptive Radiotherapy for Lung Cancer', Seminars in Radiation Oncology, doi:10.1016/j.semradonc.2009.11.003
Figure 1) Initial tumor volume vs. volume change. Figure 2) Tumor motion vs. diaphragm distance.

Figure 3) Reference position.

Figure 4) Tumor motion ratio vs. volume change. The red line is drawn at a 40% volume change. Lesions to the right experienced more than this much change, and to the left, less.