Purpose/Objective(s): For estimating internal target volume (ITV) for lung cancer, it is a common practice to use the maximum intensity projection (MIP) from a given 4DCT image set. In this approach, it is assumed that MIP images would capture the maximum extent of the tumor motion during the patient simulation. However, due to the finite CT gantry rotation speed and the irregularities in patient breathing patterns, the true tumor motion may not be captured for all patients. In fact, MIP images have been shown to underestimate the tumor motion range in cases of significant amplitude variation. Why and to what extent do MIP images under estimate the true tumor motion are important questions in lung cancer radiotherapy since treatment is prescribed based on the target size estimated from MIP.

Materials/Methods: The measurements were performed with a cork lung phantom placed on an in-house built mechanical moving platform. The motor-driven platform can simulate realistic tumor motion by reading motion trajectories measured using devices such as the Real-Time Position Management (RPM) system. In the cork lung phantom (10x15x18cm, 0.295 g/cm³), an acrylic plate simulating the lung tumor (0.5x5x5cm, 1.19 g/cm³) was inserted. Ten randomly selected patient RPM files (who underwent 4DCT simulation) were used to simulate A-P abdomen motion directly correlated to S-I lung motion. From the output RPM files, each position of the inspiration and expiration amplitude peaks over the entire breathing sample were used to calculate the mean peak-to-peak (mPP), maximum inspiration peak (mIP), and maximum expiration peak (mEP) values. In theory, the reconstructed MIP images would capture the maximum inspiration-to-expiration peak (mIP-to-mEP) motion range. 4DCT scans were performed for each case and the acrylic target was contoured, on the MIP images, with its dimensions subsequently recorded.

Results: The mPP ranged from 0.38 to 1.67 cm (average, 0.63 ± 0.41 cm), whereas the mIP-to-mEP ranged from 0.57 to 2.63 cm (average, 1.25 ± 0.58 cm) among the patients. For MIP-ITV (minus the true acrylic dimension), however, a range from 0.62 to 1.83 cm (average 0.93 ± 0.36 cm) was observed. Compared with the MIP-ITV dimensions, the mPP underestimated on average by 0.29 ± 0.16 cm, whereas the mIP-to-mEP overestimated on average by 0.33 ± 0.35 cm. The largest uncertainties in MIP-ITVs were due to large intra-scan uncertainties in breath amplitudes.

Conclusions: MIP-ITV underestimates the maximum tumor motion as represented by mIP-to-mEP but consistently overestimates the mPP value. This study shows that MIP-ITV underestimated the maximum tumor motion by 0.33 cm on average. Based on this finding, we recommend adding extra 3-mm margin in superior-inferior direction for MIP-based treatment planning.

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