

Purpose: To maintain accuracy, respiratory surrogate-based intra-fraction tumor motion models must be updated periodically. The purpose of this study was to determine how best to time respiratory surrogate-based tumor motion model updates by comparing a novel statistical process control (SPC) method, based on external measurements alone, to three direct measurement methods in clinical use.

Methods: Position datasets recorded during 121 treatment fractions from 61 lung cancer patients were analyzed. Datasets included 26 Hz localizations of three surrogate markers affixed to the torso as well as tumor localizations from intermittent (approximately once per minute) stereoscopic radiographs. Partial-least-squares regression models of tumor position from marker motion were created from six concurrent tumor localizations. At each radiographic localization, model accuracy was assessed and model rebuilding with the six most recent tumor localizations was considered. Model updates were timed according to four methods: (1) never, (2) when an SPC metric (either Hotelling's T^2 or the input-variable-squared-prediction-error) based on surrogate measurements alone exceeded 70th percentile confidence limits, (3) when model error >3mm, and (4) at each radiographic localization.

Results: Radial tumor displacement prediction errors (mean +/- standard deviation) for the four schema described above were 2.4 +/- 1.2 mm, 1.9 +/- 0.9 mm, 1.9 +/- 0.9 mm, and 1.7 +/- 0.9 mm, respectively. The no-update error was significantly larger than errors of the other methods, which did not differ significantly. Mean update counts were 0, 3.3, 9.2, and 18.5, respectively, over 20 minutes. SPC-timed updates were 36% and 18% as frequent as error-based and each-localization updates.

Conclusions: Tumor localization accuracy improved significantly with model updates. Despite comparable tumor localization accuracy amongst the update methods, there were significantly fewer SPC-timed model updates than error-timed updates. This study proves the feasibility of timing model updates through analysis of external measurements alone, without direct tumor localization.

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