AbstractID: 12668 Title: Online Monitoring and Error Detection of Real-Time Tumor Displacement Prediction Accuracy Using Statistical Process Control

Purpose: To investigate two statistical process control (SPC) metrics, the Hotelling (T^2) statistic and the input-variable-squared-prediction-error ($Q^{(X)}$), for predicting degradation in real-time tumor displacement accuracy without explicit measurement of tumor displacement.

Method and Materials: Independently but concurrently localized tumor and external surrogate positions from a database of Cyberknife Synchrony™ cases (130 treatment fractions from 63 lung tumors, 10 fractions from 5 liver tumors, and 48 fractions from 23 pancreas tumors) were analyzed. Each fraction consisted of 40-112 measurements obtained at an average rate of 0.018 Hz. The first 10 measured internal/external samples in each fraction were used to create fraction-specific models of tumor displacement using external surrogates. The regression coefficients relating the 3D positions of the 3 skin markers to the 3D tumor positions were calculated using partial-least-squares (PLS) regression. The PLS model was applied to all subsequent localizations in the fraction. The T^2- and $Q^{(X)}$-statistics in the training data were used to develop 90^{th}, 95^{th} and 99^{th} percentile ranges of expected T^2 and $Q^{(X)}$ values. The sensitivities and specificities of T^2, $Q^{(X)}$, $T^2 \cup Q^{(X)}$, and $T^2 \cap Q^{(X)}$ for predicting real-time tumor displacement errors greater than 3mm and 5mm were determined.

Results: The T^2, $Q^{(X)}$, $T^2 \cup Q^{(X)}$, and $T^2 \cap Q^{(X)}$ statistics' sensitivities and specificities varied with error threshold and acceptable percentile ranges of values. In general, the $Q^{(X)}$ statistic was associated with high sensitivity and low specificity, while the T^2 statistic was associated with moderate sensitivity and moderate specificity. For 90^{th} percentile T^2, 99^{th} percentile $Q^{(X)}$ and 3 mm error, the sensitivities of T^2, $Q^{(X)}$, $T^2 \cup Q^{(X)}$, and $T^2 \cap Q^{(X)}$ were 69%, 88%, 92%, and 64%, respectively, and the specificities were 62%, 37%, 28%, and 72%, respectively.

Conclusion: This study illustrates the feasibility of SPC metrics for detecting breakdowns in tumor displacement prediction accuracy using external sensors.

Conflict of Interest: Funded by NIH grant CA 124766