2026 JULY 19–22 VANCOUVER, BC
JOINT AAPM | COMP MEETING

Dosimetric Impact of Deviations from Planned Breath-hold In Surface-Guided Liver SBRT

Tristan K. Gaddis, PhD; Andy T. Clark, PhD; **Teh Lin, PhD**; C-M Ma, PhD
Fox Chase Cancer Center, Philadelphia, PA

ABSTRACT

Surface-guided radiation therapy (SGRT) uses external surface motion as a surrogate for internal target position. While strict SGRT tolerances (typically ±1mm) are common, they may still be permissive for patients with small surface excursions. In these cases, a patient could drift into respiratory phases outside the expected breathing range predicted by the miniMIP built based on the skin excursion tolerances. This study evaluates internal motion and the dosimetric impact of small deviations beyond the clinically selected miniMIP.

Fifteen liver SBRT patients treated with end-expiration breath-hold (EEBH) and <2 mm surface excursion within the clinically selected miniMIP were analyzed. To simulate a scenario where breathing extends slightly past the planned range, the phases included in the miniMIP were expanded to allow for an additional 1mm of surface motion. Internal fiducial displacement was measured between the original and extended ranges. The maximum displacement along the dominant direction was applied as an isocenter shift to the original plan without reoptimization. PTV D95% and GTV D99% were calculated for the original and shifted plans to assess coverage compromise.

Extending the miniMIP by 1mm revealed additional fiducial motion in all patients, with a mean internal amplitude increase of 3.7 ± 1.8mm (maximum: 6.4mm). Worst-case shifts reduced PTV D95% by a mean of 12.2 ± 3.1% (maximum reduction: 33.6%). GTV D99% changed by a mean of 4.1 ± 2.0%. While some cases demonstrated improved GTV coverage, the maximum reduction was 24.0%.

Internal fiducial motion can be disproportionately large relative to surface motion, especially for patients with minimal surface excursion. While PTV-level dosimetry was highly sensitive to worst-case motion, GTV coverage remained relatively robust, suggesting standard planning margins effectively protect the gross tumor volume. However, these findings underscore the importance of patient-specific characterization of surrogate-internal motion relationships to ensure total coverage.

CONTACT

Tristan K. Gaddis
Fox Chase Cancer Center
333 Cottman Ave, Philadelphia, PA 19111
Tristan.Gaddis@fccc.edu

FOX CHASE CANCER CENTER
TEMPLE HEALTH

INTRODUCTION

Surface-guided radiation therapy (SGRT) assumes that surface stability equates to internal stability. However, for patients with minimal surface excursion (<2 mm), standard clinical tolerances (±1 mm) can inadvertently mask significant internal motion. A patient could theoretically drift into a breathing phase outside the planning miniMIP without exceeding the set SGRT tolerance. This study examines the dosimetric impact of such internal motion, evaluating the dosimetric risk when a patient's breathing baseline shifts to the extreme edge of the allowable tolerance.

METHODS AND MATERIALS

Fifteen liver SBRT patients were selected based on high surface stability (<2 mm excursion) within the clinically selected planning miniMIP. To simulate a scenario where the breath-hold baseline is captured at the extreme edge of the miniMIP range, the range was extended to allow for an additional 1 mm of surface motion (e.g., expanding from 30–60% to 20–80%) on a patient-specific basis. Internal fiducial positions were measured and compared between the clinically selected miniMIP and the extended miniMIP. To evaluate the dosimetric impact of such deviations from the miniMIP range, shifts were applied along the direction of maximum shift (Superior-Inferior, Anterior-Posterior, or Left-Right). Standard dose criteria for the Planning Treatment Volume (PTV) and the Gross Tumor Volume (GTV), PTV D95% and GTV D99%, were evaluated for the original and shifted plans.

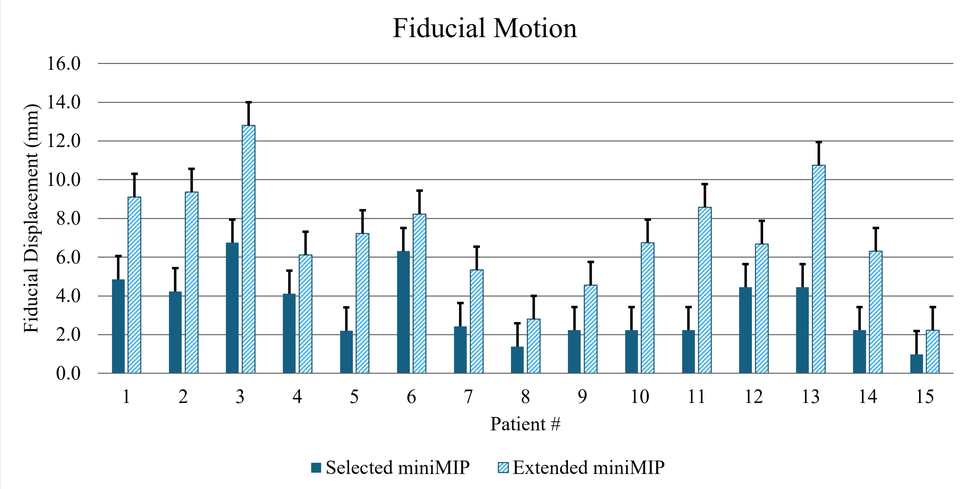

Figure 1. Fiducial displacement within the clinically selected miniMIP range and the extended miniMIP range for each patient. Error bars represent measurement uncertainty as determined by voxel size of the 4DCT, 1.2 mm.

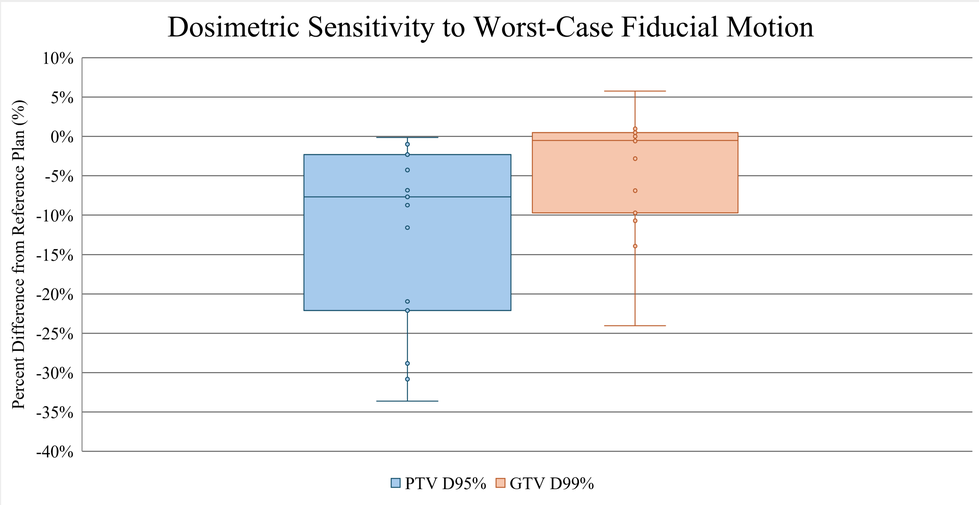

Figure 2. Percent differences between the D95% of the PTV and the D99% of the GTV for the original plan and the fiducial motion shifted plan.

RESULTS

Extending the surface window by just 1 mm revealed increased internal motion in all cases as shown in Figure 1, confirming that internal anatomy is more mobile than the surface in this cohort. This underscores that low surface amplitude does not guarantee internal immobility as shown in previous studies.[1-3] PTV coverage (D95%) proved highly sensitive to these shifts, with significant reductions observed across the group (mean reduction: 12.2%) as seen in Figure 2. However, GTV coverage (D99%) remained more robust (mean deviation: 4.1%). While some GTV coverage loss was observed (max: 24.0%), other cases showed improved coverage depending on the shift direction. Standard ITV/PTV margins appear highly effective at protecting the GTV even when drifting outside of the miniMIP range. However, the degradation of PTV coverage suggests that for patients with very shallow breathing, patient-specific characterization of the surface-internal relationship is critical to ensuring robust dosimetry. It is important to note that the likelihood of a patient remaining in these worst-case positions is low, as these shifts represent the extreme border of allowable motion. As such, this analysis is intended to characterize potential dosimetric risk under plausible but infrequent conditions, rather than predict routine clinical performance.

CONCLUSIONS

Extending the miniMIP range by just 1 mm revealed an expected increase in internal fiducial motion across all patients, highlighting a potential issue with tight surface tracking margins for EEBH patients. While PTV coverage (D95%) was highly sensitive to worst-case shifts, GTV coverage (D99%) remained relatively robust, indicating that standard planning margins effectively maintained GTV coverage against worst-case deviations. Therefore, patient-specific characterization of the surface-internal relationship is critical for ensuring robust dosimetry, particularly for patients with shallow breathing.

REFERENCES

1. Wang, Guangyu, et al. "Correlation of optical surface respiratory motion signal and internal lung and liver tumor motion: a retrospective single-center observational study." *Technology in Cancer Research & Treatment* 21 (2022): 15330338221112280.
2. Leipold, Vanda, et al. "Optimizing Choice of Skin Surrogates for Surface-Guided Stereotactic Body Radiotherapy of Lung Lesions Using Four-Dimensional Computed Tomography." *Cancers* 16.13 (2024): 2358.
3. Keall, Paul J., et al. "The management of respiratory motion in radiation oncology report of AAPM Task Group 76 a." *Medical physics* 33.10 (2006): 3874-3900.

© Poster Template by Genigraphics® 1.800.790.4001 www.genigraphics.com