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

A Quantitative Workflow to Reduce Vertical Setup Uncertainty in DIBH Radiotherapy Using the LAP LUNA 3D SGRT System

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ABSTRACT

This study introduces a quantitative SGRT-based workflow to improve the accuracy of Deep Inspiration Breath Hold (DIBH) radiotherapy. Before any imaging, patients were coached to their planned breath-hold amplitude using the SGRT system.

An analysis of the remaining setup errors, determined by IGRT, revealed that this pre-verification step significantly improved setup precision. Specifically, the vertical (breath-hold dimension) couch shifts were much smaller and less variable than shifts in the longitudinal and lateral directions.

The workflow also proved to be an effective screening tool, identifying patients who could not consistently reproduce their breath-hold, thereby preventing geometrically compromised treatments. This SGRT method provides a robust, non-radiographic way to ensure DIBH reproducibility and enhance treatment accuracy.

INNOVATION/IMPACT

The innovation is the use of a quantitative, non-radiographic verification step to confirm the DIBH amplitude before committing to volumetric imaging. Our hypothesis is that this procedural control will selectively reduce the magnitude of residual setup errors in the vertical dimension. This analysis provides the evidence to justify the workflow as a necessary component of a high-fidelity DIBH program..

METHODS AND MATERIALS

- At CT simulation, a reference DIBH amplitude was recorded using the LAP LUNA 3D SGRT system's motion tracking ROI. At each treatment, patients were coached to match this amplitude (±5 mm tolerance) prior to any imaging.
- Following this SGRT verification, IGRT (CBCT and/or port films) was performed to determine residual setup errors.
- This workflow was implemented for four left-breast patients over 71 fractions. The residual translational couch shifts (VRT, LNG, LAT) from 36 fractions requiring non-zero corrections were analyzed via box plot to compare setup variability.
- The remaining 35 fractions required zero couch correction post-IGRT, representing days where the initial SGRT-guided setup required no correction

RESULTS

- The mean deviation between the planned CT amplitude and the pre-IGRT amplitude was 0.62 mm, with coaching required in ~60% of fractions.
- The workflow's efficiency is demonstrated by analyzing the residual setup errors remaining after the SGRT amplitude verification is complete. The core of the workflow is shown in Figure 1A, and the resulting couch shift data is presented in the box plot of Figure 1B.
- The mean deviation between the planned CT amplitude and the pre-IGRT amplitude was 0.62 mm, with coaching required in ~60% of fractions.
- Fig 1B shows a statistical analysis of the 38 non-zero couch shifts and thus provide quantitative evidence of the workflow's benefit. From the result:
  - the vertical axis, VRT (Controlled Dimension) exhibited the highest precision. The corrections were tightly clustered around a median of -0.5 mm, indicating a small, systematic bias. The interquartile range (IQR), spanning from -2.3 mm to 0 mm, was the smallest of the three axes, confirming minimal setup variability in the direction of SGRT verification.
  - The Longitudinal axis, LNG demonstrated the lowest precision. While the median shift was negligible at 0 mm, the data showed significant variability, with the largest IQR and a wide overall range of corrections from -4.2 mm to +3.2 mm. This confirms that large, random errors persist in this axis.
  - Finally, the Lateral axis, LAT showed moderate precision. The median shift was +1.2 mm, with the interquartile range (IQR), spanning from 0 mm to 2.4 mm. Two significant outliers of +6.7 mm and -5.3 mm were noted.

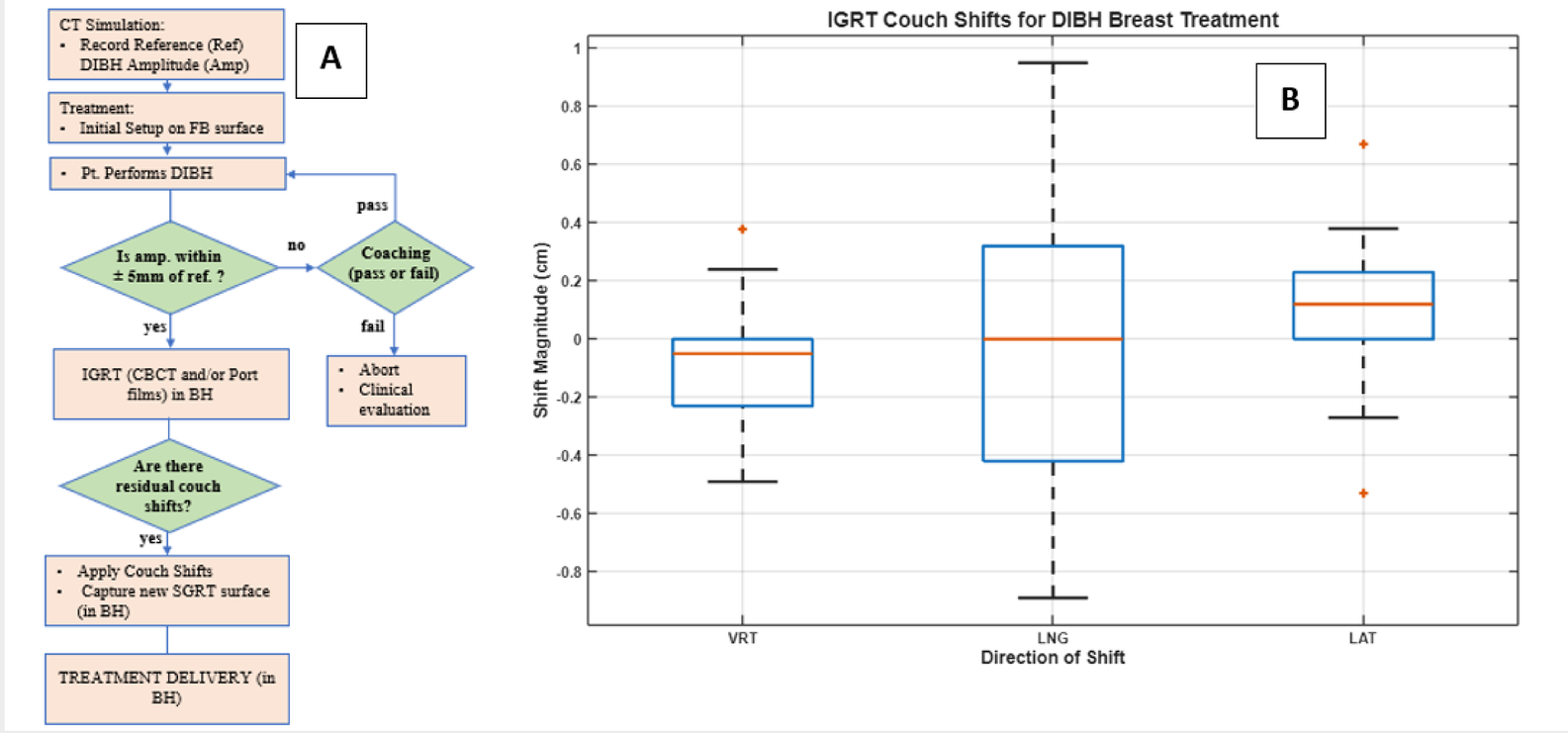

Fig. 1. (A) Generalized workflow for DIBH incorporating SGRT amplitude verification using LAP LUNA 3D SGRT system. (B) Box plot analysis of IGRT-derived translational corrections post-SGRT amplitude verification for DIBH patients .

CONCLUSIONS

This SGRT-based workflow provides a robust, quantitative, and non-radiographic method to ensure the geometric reproducibility of DIBH prior to imaging. It functions as an effective pre-treatment screening tool, helping to identify and exclude patients who cannot consistently reproduce their breath-hold, thereby avoid unnecessary imaging dose and prevent geometrically compromised treatments. The demonstrably lower variability in vertical couch shifts compared to the other axes provides definitive quantitative evidence that this SGRT-based amplitude verification workflow actively improves setup precision in the primary breath-hold dimension, leading to more reliable and accurate treatment delivery.

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