An End-to-End Assessment of Localization and Dosimetric Accuracy of the LAP LUNA 3D SGRT System

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ABSTRACT

This study evaluates the geometric and dosimetric accuracy of the new LAP LUNA 3D surface-guided radiotherapy (SGRT) system.

An end-to-end test was performed using an anthropomorphic phantom, where the phantom was positioned using only SGRT guidance for the delivery of a 5 Gy VMAT plan.

Subsequent CBCT imaging revealed that the initial SGRT setup was highly accurate, with residual translational errors of ≤1 mm and rotational errors of ≤0.1°.

Furthermore, the absolute dose delivered following the SGRT-only setup was nearly identical (<0.1% deviation) to the dose measured after a conventional CBCT-based correction.

These results demonstrate that the LUNA system meets the stringent geometric tolerances for SRS/SBRT (AAPM TG-302) and can be used with high confidence as a primary modality for patient positioning. Using an anthropomorphic.

INNOVATION/IMPACT

The clinical impact of this study lies in establishing the baseline, intrinsic accuracy of the novel LAP LUNA 3D SGRT system. While Surface-Guided Radiotherapy (SGRT) is a standard of care, its accuracy is often convolved with patient-specific uncertainties (e.g., skin motion, deformation), as the external surface is not always a perfect surrogate for internal anatomy. By using a rigid anthropomorphic phantom, this study decouples system performance from patient variables. This allows for a direct measurement of the system's fundamental geometric and dosimetric accuracy. Establishing this high-accuracy baseline is a critical prerequisite for clinical implementation, as it informs the clinical judgment required when applying the system to non-rigid patient scenarios.

METHODS AND MATERIALS

An anthropomorphic end-to-end phantom (CIRS Model 036A) was imaged, with an Exradin A16 ion chamber (Standard Imaging Inc, Middletown, WI) inserted at the target isocenter.
A single-fraction 5 Gy VMAT plan was generated using the Eclipse TPS. The DICOM dataset was exported to the SGRT system. The phantom was first positioned using only LAP LUNA SGRT guidance, and the residual real-time deltas were recorded.
The plan was delivered, and the absolute dose was measured. Subsequently, a CBCT was acquired to determine setup corrections based on internal anatomy. These image-guided corrections were recorded, the phantom position was adjusted, and the plan was re-delivered to establish a baseline dosimetric measurement.

To ensure the validity of the SGRT measurements, two methodological points are critical:

- **High-Fidelity Reference Surface:** The external body contour, which serves as the reference for the SGRT system, was meticulously generated. After an initial automated thresholding in the Eclipse TPS, the surface was manually inspected and edited to close all topological gaps. This created a complete, continuous surface essential for accurate SGRT registration.
- **Region of Interest (ROI) Definition:** Within the LAP LUNA software, a specific ROI was defined on the phantom's surface. This ROI designates the precise area used by the system's algorithms to calculate and display the real-time translational and rotational setup deltas, ensuring a consistent and clinically relevant evaluation.

RESULTS

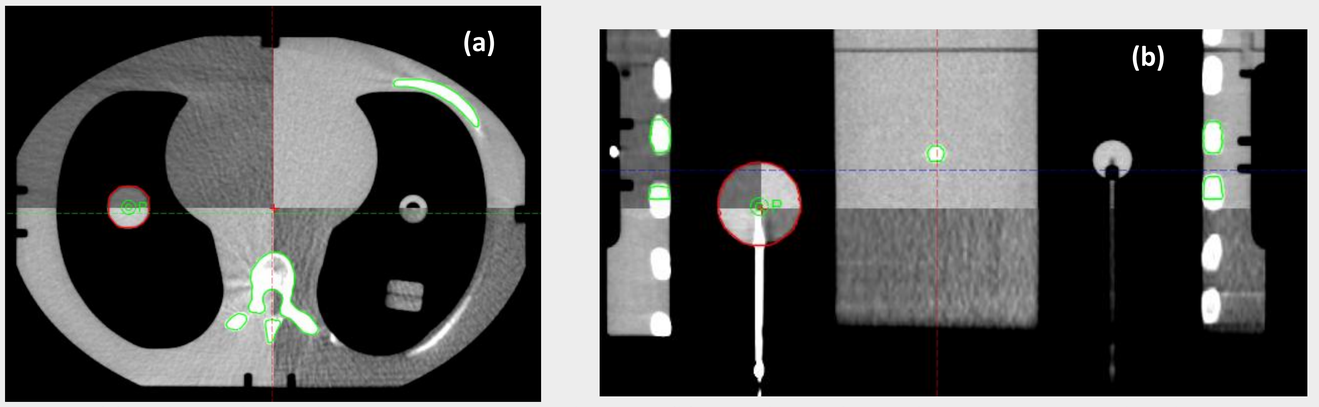

Fig. 1. (a) Axial view of internal anatomy registration based on CBCT. (b) Coronal view of internal anatomy registration based on CBCT.

Table. 1. Result of residual setup errors post-SGRT alignment (SGRT vs. CBCT)

Axis	VRT (mm)	LNG (mm)	LAT (mm)	PITCH(°)	ROLL(°)	RTN (°)
Delta	0.8	0.9	-0.9	0.1	0.1	0.0

DISCUSSION

- The geometric accuracy of the SGRT system was quantified by comparing the residual error from the SGRT-guided setup to that derived from CBCT registration. The results demonstrate a high degree of accuracy, meeting the stringent tolerance for SRS/SBRT applications (≤ 1mm & ≤1°).
- The end-to-end dosimetric analysis yielded two primary findings:
  - **SGRT vs. IGRT Equivalence:** The dose delivered after SGRT-only setup was **0.0% different** from the dose delivered after CBCT-based correction. This confirms that for a rigid target, the geometric accuracy of the SGRT system translates to dosimetric equivalence with conventional image guidance.
  - **End-to-End System Accuracy:** The absolute dose measured with the SGRT-guided setup was **-3.32%** relative to the TPS planned dose. This overall deviation for the entire treatment chain is well within the ≤5% tolerance recommended by AAPM MPPG 5.a for an end-to-end IMRT/VMAT test.

CONCLUSIONS

This end-to-end assessment demonstrates the LAP LUNA 3D SGRT system achieves a high degree of geometric localization accuracy, with translational and rotational deviations **within 1 mm and 0.1°**, respectively. The resulting dosimetric agreement was negligible (<0.1%) when compared to a CBCT-based setup, indicating high confidence in SGRT as a primary positioning modality. The observed geometric accuracy meets the ≤1 mm tolerance for SRS/SBRT recommended by AAPM TG-302. Furthermore, the overall end-to-end dosimetric accuracy of -3.32% (measured vs. plan) is well within the ≤5% tolerance recommended by AAPM MPPG 5.a for complex IMRT/VMAT delivery, validating the entire treatment chain.

REFERENCES

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