Impact of Motion on Dose Calculation Differences between Halcyon and TrueBeam Hypersight Imaging Systems

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ABSTRACT

The purpose of this study was to compare HyperSight imaging between an O-ring Halcyon and a C-arm TrueBeam, with emphasis on the impact of motion on dose calculations.

A CIRS Lung Phantom was scanned on both systems under still and motion conditions using cycle times of 4 and 8 s and amplitudes of 5 and 20 mm. The datasets were registered using the still images, and contours were defined based on the known target size and motion. A treatment plan was optimized on the Halcyon dataset, copied to the TrueBeam dataset, and recalculated in Eclipse. Dose distributions were compared using 3D gamma analysis and ITV DVHs.

Differences were observed even in the still condition and increased with larger motion amplitudes and longer cycle times. These results suggest that CT-number differences between reconstruction protocols are a primary source of variation and that motion further amplifies the resulting dose differences.

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INTRODUCTION

The updated HyperSight system improves scan speed and image quality, including higher contrast-to-noise ratio, lower noise, and improved CT-number accuracy. However, previous evaluations focused mainly on O-ring systems and image-quality metrics, without assessing whether differences between Halcyon and TrueBeam imaging affect dose calculations, particularly under motion. As our institution considers implementing HyperSight on both platforms, this study compares dose distributions calculated from Halcyon images acquired at Barnes-Jewish Hospital and TrueBeam images acquired at West County Hospital, both located in the St. Louis, Missouri area, under stationary and controlled motion conditions.

Objective: <u>To quantify dose calculation differences between Halcyon and TrueBeam HyperSight images under stationary and controlled respiratory motion conditions.</u>

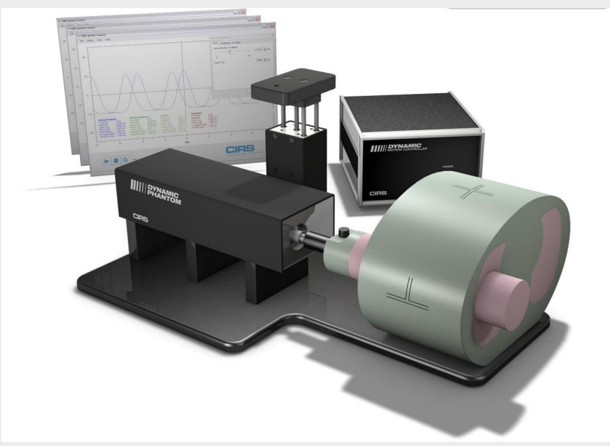

Figure 1: CIRS Dynamic Thorax Phantom and motion-control system used to simulate respiratory motion during image acquisition.Sun Nuclear[1]

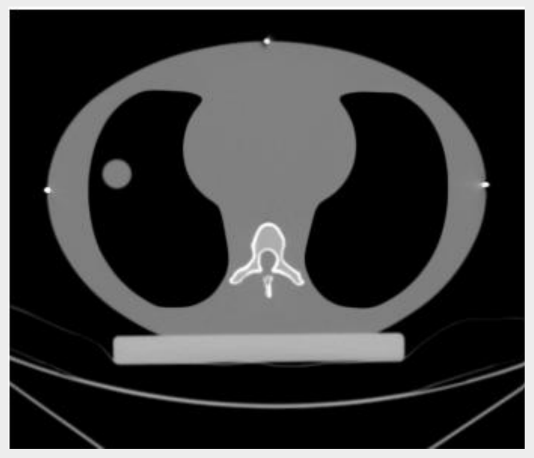

Figure 2: Representative axial CT image of the CIRS Dynamic Thorax Phantom showing the lung-equivalent regions, anthropomorphic spine, and soft-tissue target.

METHODS AND MATERIALS

A CIRS Lung phantom (shown on Figure 1 above) was imaged on a TrueBeam system at West County Hospital and a Halcyon system at BJH under five motion conditions: stationary, 4 s/5 mm, 4 s/20 mm, 8 s/5 mm, and 8 s/20 mm. These settings were selected to evaluate whether HyperSight's faster acquisition reduces motion-related blurring and dosimetric differences.

The datasets were registered using the stationary scans, and contours were defined from the known target dimensions and motion amplitudes to maintain consistent anatomy across all images. A treatment plan was optimized on the Halcyon dataset in Eclipse, transferred unchanged to the TrueBeam datasets, and recalculated. Dose distributions were compared using 3D gamma analysis in Python with PyMedPhys, together with DVH comparisons generated in Eclipse.

RESULTS

Dose differences were observed between the Halcyon and TrueBeam datasets under all evaluated conditions, including the stationary scan. Using the 1%/1 mm criterion, gamma pass rates decreased with increasing motion amplitude and longer cycle times, from 91.32% in the still condition to 69.75% for the 8 s/20 mm condition (Table 1). In contrast, pass rates using the 2%/2 mm criterion remained above 98% for all conditions. The gamma heatmaps show the spatial distribution of dose agreement for the stationary condition. Nearly all evaluated points passed the 2%/2 mm criterion, resulting in a 99.97% pass rate (Figure 3). Under the stricter 1%/1 mm criterion, localized regions with gamma values greater than 1 were observed, reducing the pass rate to 91.32% (Figure 4).

DVH differences were also observed and were more pronounced under increased motion conditions (Figure 5).

Table 1. 3D gamma results for different motion conditions

Motion Condition	2% / 2 mm	1% / 1 mm
Still	99.97%	91.32%
4 s / 5 mm	99.13%	89.15%
4 s / 20 mm	99.17%	87.00%
8 s / 5 mm	98.85%	84.53%
8 s / 20 mm	98.27%	69.75%

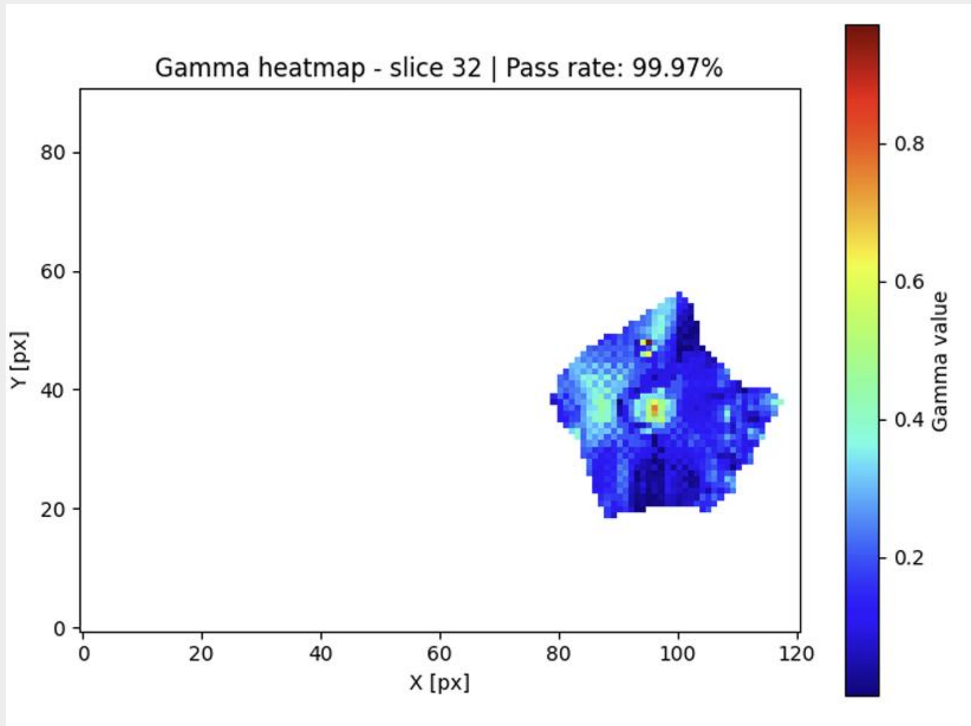

Figure 3: Representative gamma heatmap comparing the Halcyon and TrueBeam dose distributions under the stationary condition using the 2%/2 mm criterion.

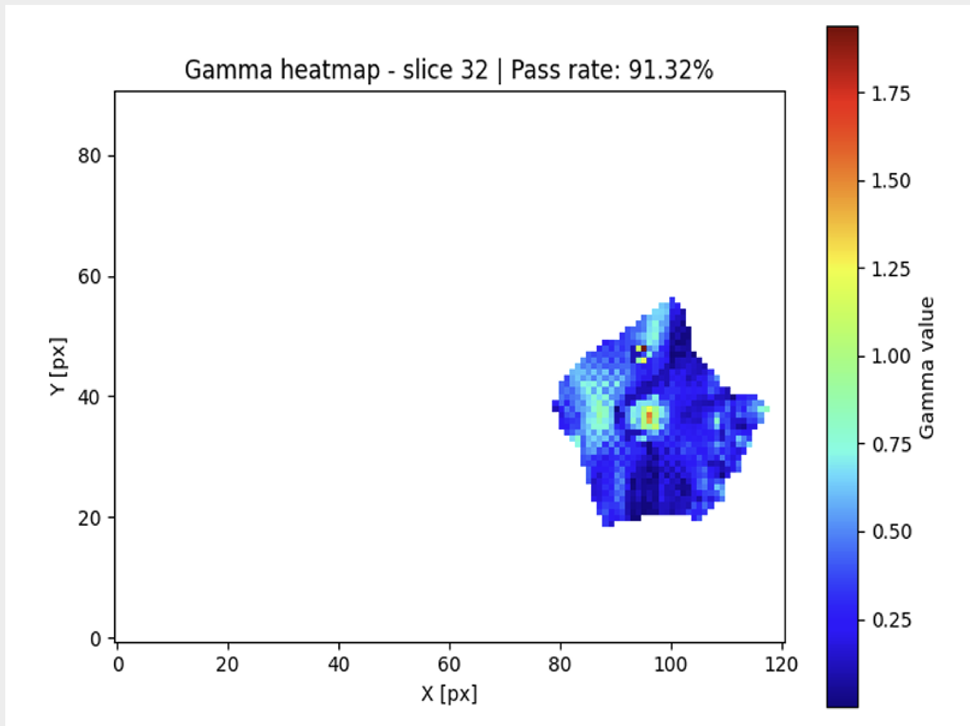

Figure 4: Representative gamma heatmap comparing the Halcyon and TrueBeam dose distributions under the stationary condition using the stricter 1%/1 mm criterion.

DISCUSSION

Measurable dose differences were observed between the Halcyon iCBCT and TrueBeam reconstructions even under stationary conditions, suggesting an underlying effect from CT-number and reconstruction-protocol differences. Motion amplified these discrepancies: 3D gamma pass rates decreased and DVH deviations increased with larger motion amplitudes and longer breathing cycles.

Although most cases passed the conventional 3%/3 mm criterion, the stricter 2%/2 mm and 1%/1 mm criteria were more sensitive to subtle dosimetric differences, particularly in motion-affected regions. Because the reconstruction protocols were not directly matched, the observed differences likely reflect the combined effects of reconstruction method and respiratory motion.

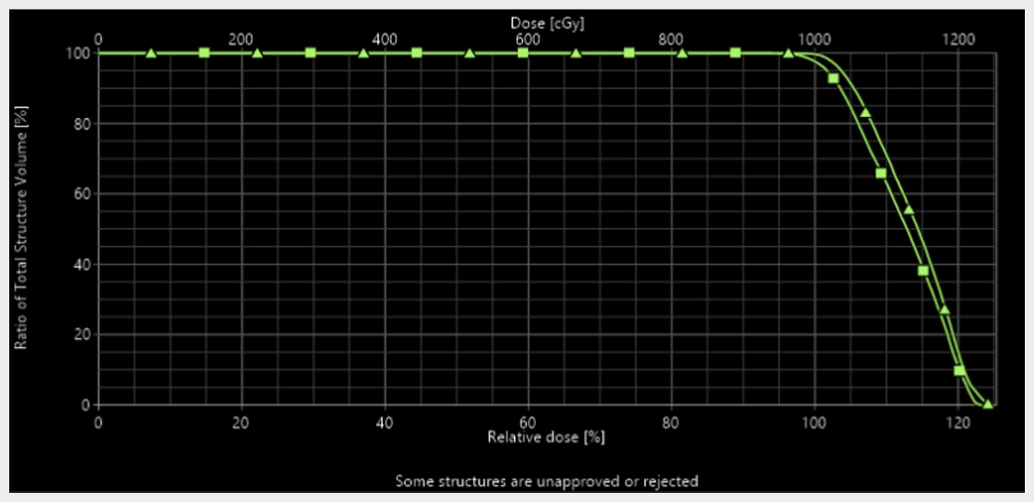

Figure 5: DVH comparison for the ITV under the 4 s/5 mm motion condition. Triangular markers represent the TrueBeam dataset, while square markers represent the Halcyon dataset. The separation between the curves in the high-dose region indicates differences in the calculated dose distribution between the two imaging systems.

FUTURE DIRECTIONS

Future work will expand this preliminary analysis by evaluating additional image-quality and dosimetric factors across different imaging conditions.

- Evaluate SNR, CNR, spatial resolution, and HU consistency.
- Include CT simulator images as a reference standard.
- Investigate motion-aware reconstruction methods.
- Extend the analysis to additional anatomical sites affected by respiratory motion.
- Explore the use of HyperSight images for treatment planning and adaptive therapy workflows.

REFERENCES

1. Computerized Imaging Reference Systems, Inc. (2021). *Dynamic Thorax Phantom: Model 008A*. Sun Nuclear Corporation.

Acknowledgements

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