

ABSTRACT

Purpose: The HyperSight upgrade on the Varian TrueBeam linac includes a larger detector panel and increases the maximum CBCT gantry rotation speed to 1.5 revolutions per minute (rpm). While enabling faster acquisition for 3D CBCT, its impact on free-breathing gated CBCT (gCBCT), which is widely used in respiratory gating radiotherapy, remains uncharacterized. The gCBCT restricts gantry rotation and kV acquisition to predefined gating windows, introducing complex mechanical dynamics (accelerations, decelerations, and “setback” maneuvers). This study evaluates the impact of increased gantry speed on gCBCT scan time, imaging dose, and image quality.

Methods: A total of 42 gCBCT scans were acquired on a HyperSight-equipped linear accelerator using gantry rotation speeds of 1.0 and 1.5 rpm. Respiratory motion was simulated using a CIRS motion platform with $\cos^4(x)$ waveforms spanning breathing periods of 3-6 s and duty cycles of 30-60% (32 scans), and with five clinical patient breathing traces (10 scans). Scan time and imaging dose were quantitatively compared between scans acquired with the two gantry speeds. Image quality was evaluated using a Catphan phantom on a QUASAR motion platform.

Results: For typical clinical breathing periods (≥ 4 s) and duty cycles (30–60%), 1.5 rpm gantry rotation reduced gCBCT scan time relative to 1.0 rpm by 15–30% with a 5–15% increase in imaging dose. For faster breathing (< 4 s) and high duty cycles ($> 50\%$), both scan time and imaging dose increased at 1.5 rpm. Image quality was comparable between the two gantry speeds.

Conclusion: Mechanical and temporal constraints in gCBCT limit the gains from faster gantry rotation. Under typical clinical conditions, HyperSight’s increased gantry speed shortens gCBCT acquisition with a modest dose increase, but in patients with rapid breathing and high duty cycles it may prolong scan time. These findings provide initial guidance for clinical use of HyperSight and for optimizing gCBCT protocols.

CONTACT

Mitchell Yu
Memorial Sloan Kettering Cancer Center
yum2@mskcc.org

Characterization of Free-breathing Gated CBCT Imaging on C-arm linac with HyperSight

Mitchell Yu¹, Xiuxiu He¹, Qiyong Fan¹, Yiming Gao¹, Wendy Harris¹, Yabo Fu¹, Weixing Cai¹, Yusuf Erdi¹, Maria Chan¹, Karen Episcopia¹, Seng Boh Lim¹, Laura Cervino¹, Tianfang Li¹, Xiang Li¹, Sean Berry¹, Jean Moran¹, Hao Zhang²

¹ Department of Medical Physics, Memorial Sloan Kettering Cancer Center, New York, NY 10065, USA

² Department of Radiation Oncology, Stanford University School of Medicine, Palo Alto, CA, 94305, USA

INTRODUCTION

❖ HyperSight Upgrade on Varian TrueBeam LINACs

- New kV imager panel
- Faster gantry rotation speed
- Software improvements

	TrueBeam	TrueBeam 4.1 HyperSight
kV panel size	40 x 30 cm	43 x 43 cm
FOV	standard	extended
Gantry rotation speed	6°/s 1 rpm	9°/s 1.5 rpm
HU Accuracy	standard	improved

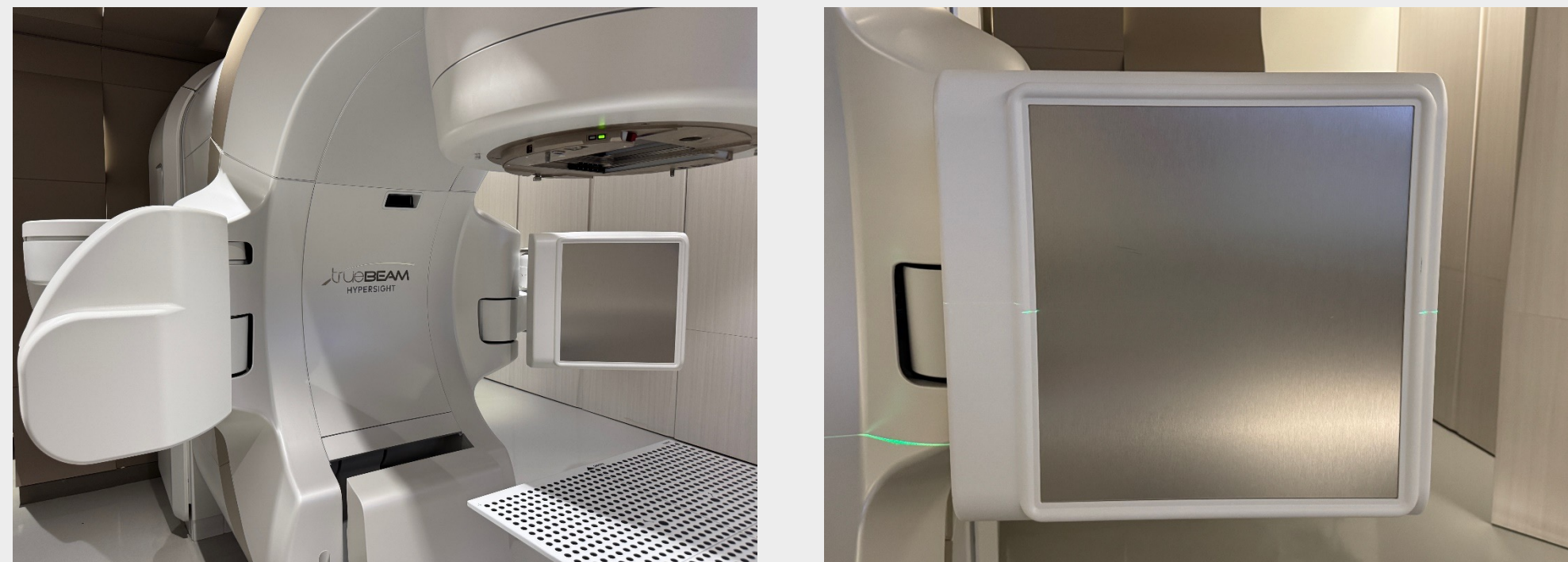


Figure 1: Varian TrueBeam linac with the HyperSight upgrade. The hardware upgrade features larger kV imager panel and faster gantry rotation speed for 3D CBCT scan.

❖ Impact of increased gantry speed on gated CBCT needs to be evaluated

- Scan time, imaging dose, and image quality

METHODS AND MATERIALS

❖ CIRS motion platform

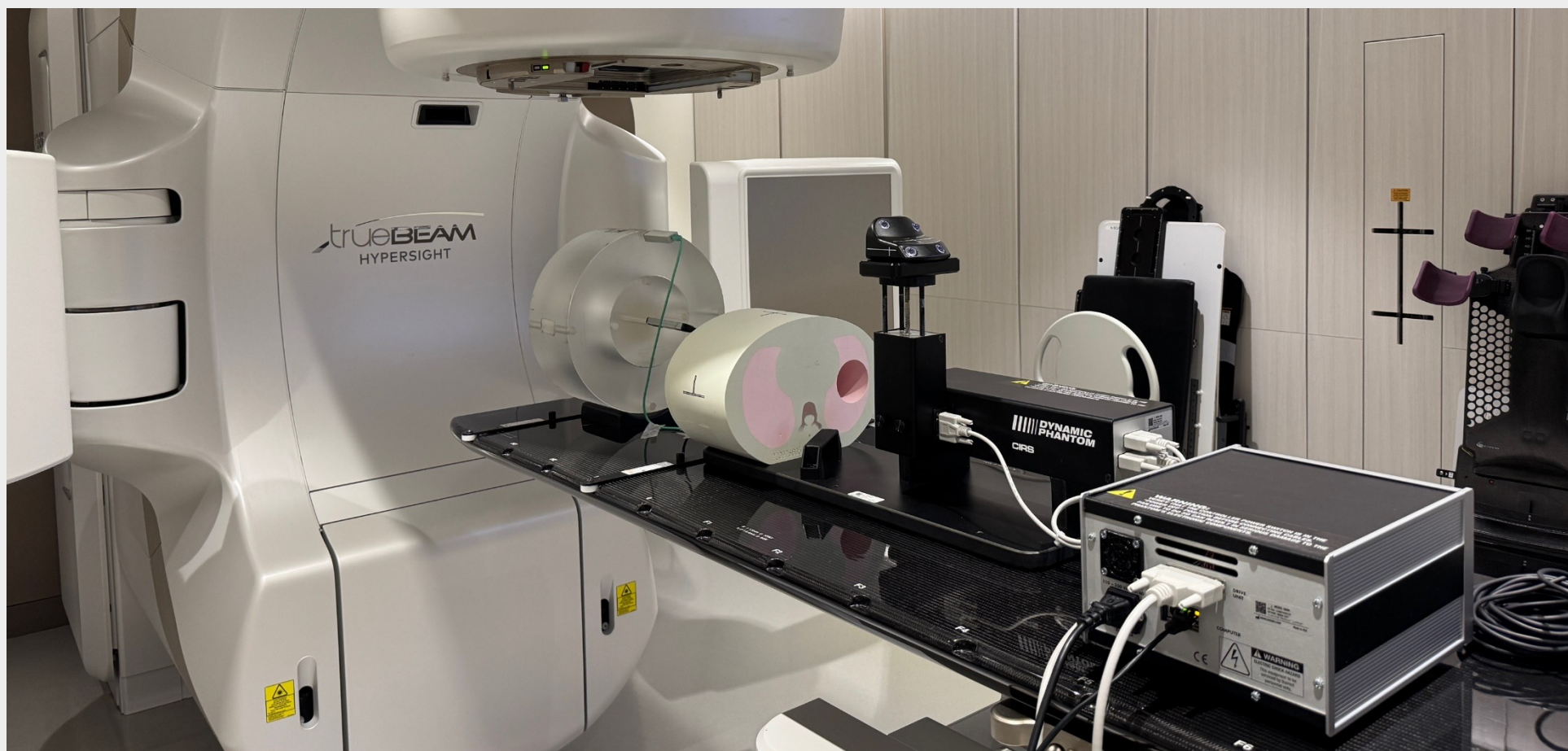
- Simulated $\cos^4$ motion
- Clinical patient breathing traces

❖ CTDI phantom and pencil chamber

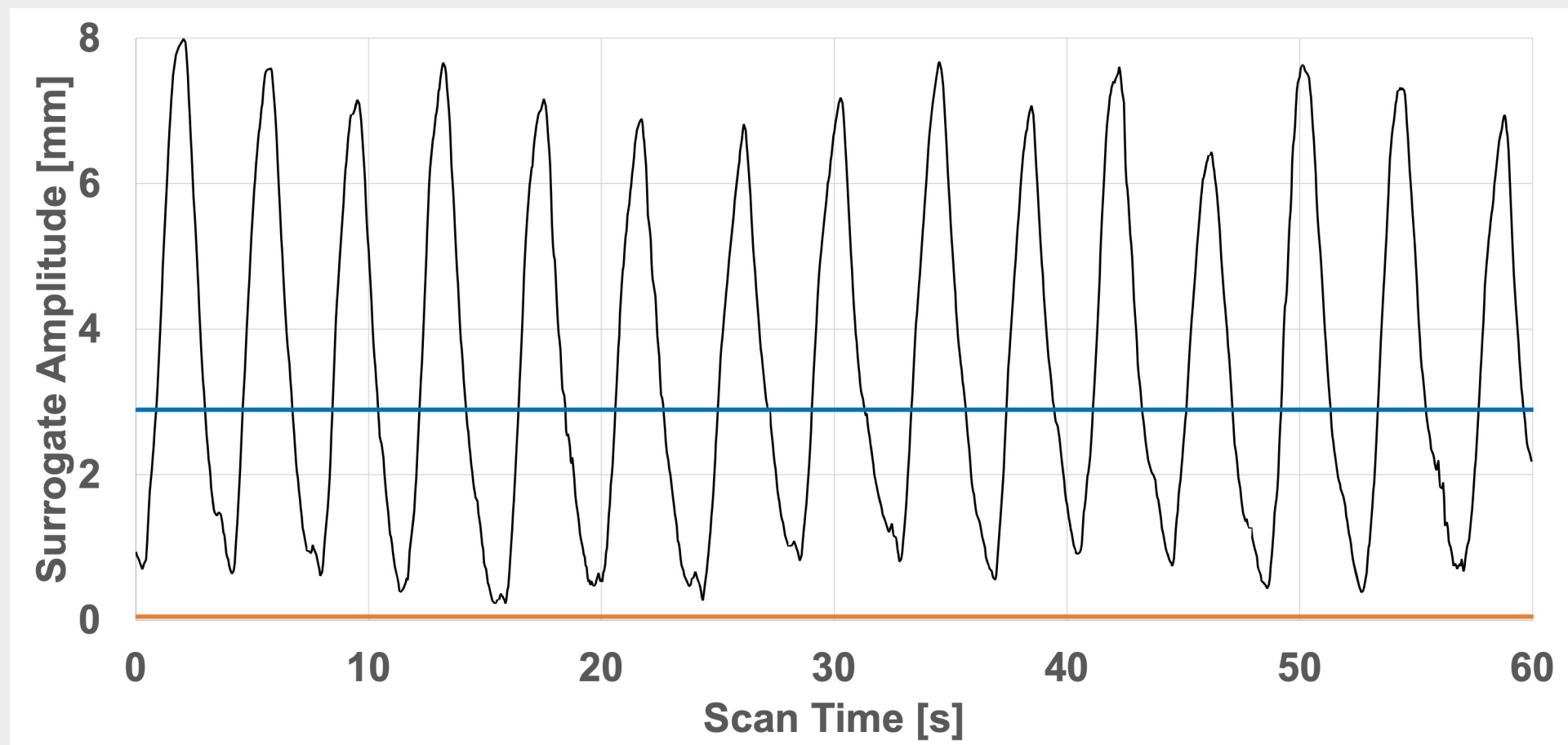
- Weighted cone-beam dose index (CDBI_w)

❖ Catphan on a QUASAR motion platform

- Image quality evaluation



(a) Experimental setup



(b) One representative clinical patient breathing trace

Figure 2: The experimental setup using a CIRS motion platform, with both simulated $\cos^4$ and clinical patient breathing traces. The CDBI_w is measured using the CTDI phantom and a pencil chamber.

RESULTS

❖ CDBI_w higher for all 1.5 rpm scans (faster gantry speed)

- Increased kV projections acquired during repeated gantry acceleration phases

❖ Scan time reduced for most clinically relevant scenarios

- Exception in shorter breathing period (< 4 s)

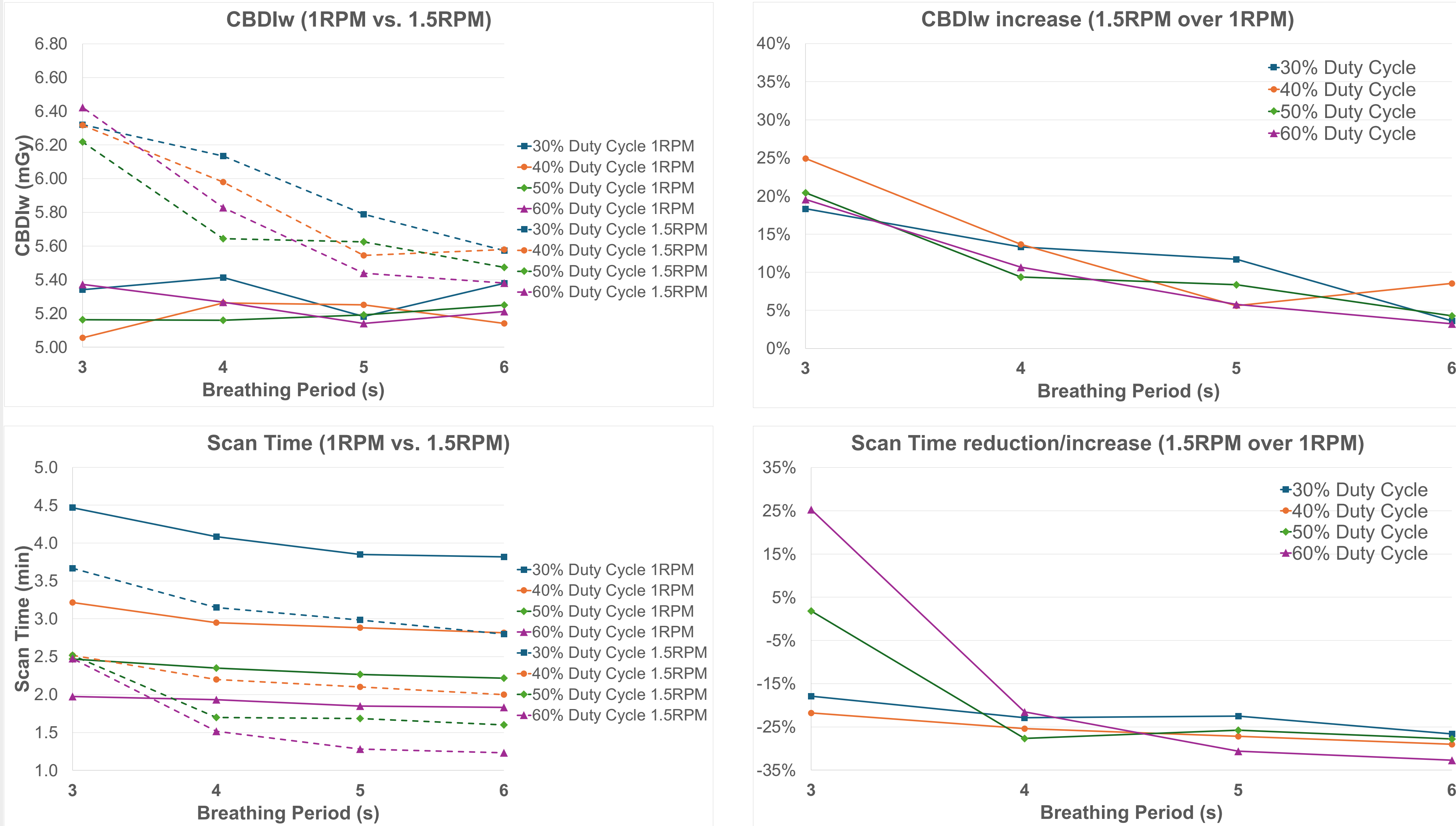
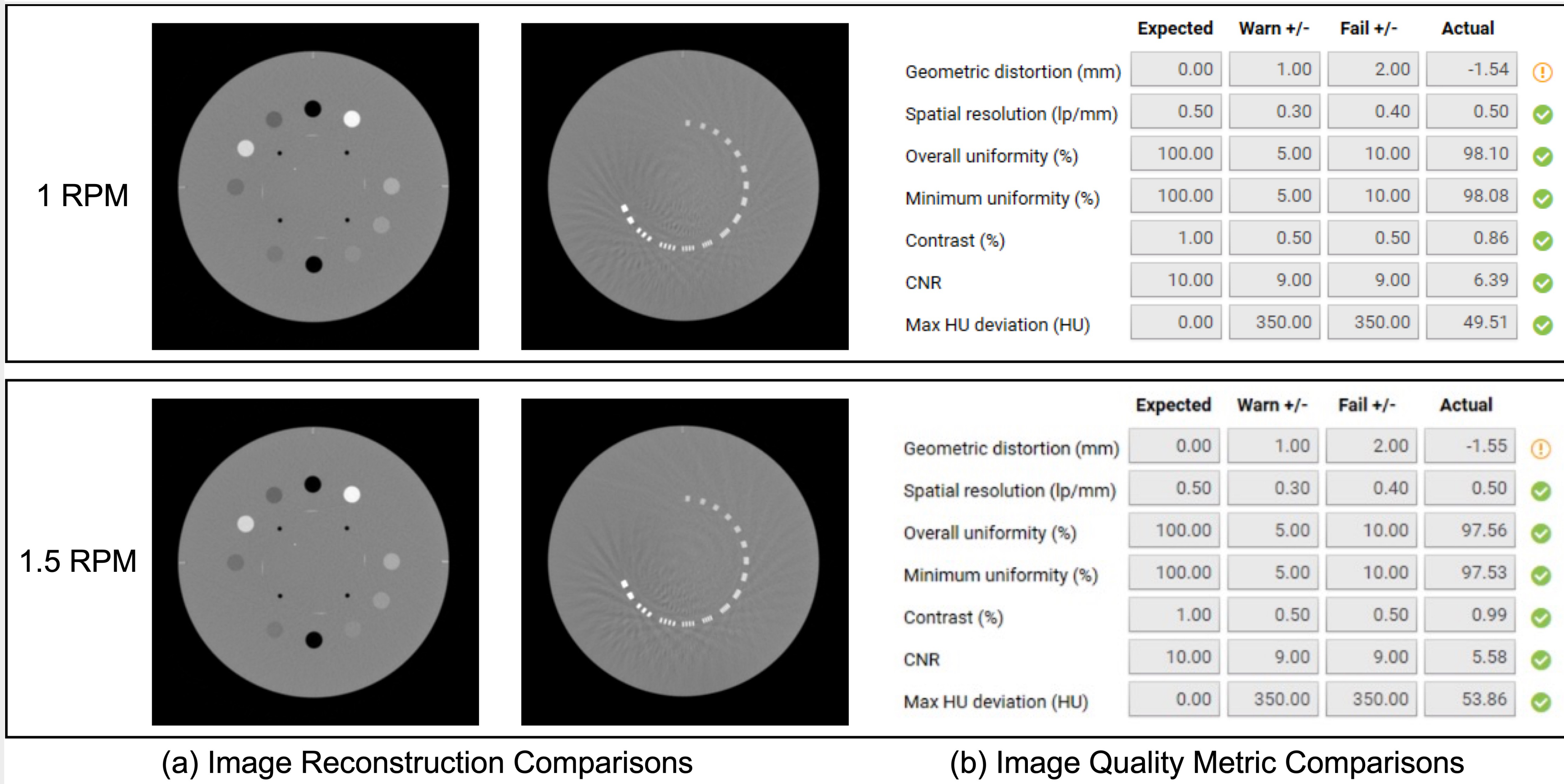


Figure 3: Comparisons of CDBI_w and scan time between the 1.5 and 1 rpm gated CBCT acquisitions for simulated $\cos^4$ motion with 30-60% duty cycles and 3-6 seconds breathing periods.

❖ Comparable gated CBCT image quality between 1.5 rpm and 1 rpm acquisitions



(a) Image Reconstruction Comparisons

(b) Image Quality Metric Comparisons

Figure 4: Gated CBCT images of Catphan phantom on the QUASAR motion platform (40% duty cycle, 5s breathing period) at 1.5 rpm and 1 rpm gantry speeds.

❖ Clinical patient breathing trace results match with simulated $\cos^4$ motion

Patient	Duty Cycle (%)	Breathing Period (s)	CDBI _w Change (w.r.t. 1 rpm)	Scan Time Change (w.r.t. 1 rpm)
#1	42.8	2.7 – 3.9	11.5%	-18.8%
#2	50.6	4.2 – 6.4	4.7%	-29.0%
#3	51.2	3.8 – 4.7	14.7%	-27.8%
#4	51.5	2.9 – 3.7	20.7%	-11.6%
#5	49.7	3.3 – 5.0	8.9%	-16.5%

CONCLUSIONS

❖ Uniform scan time reduction NOT observed for gated CBCT.

❖ HyperSight may result in longer gated CBCT scan times in patients with rapid breathing and a high duty cycle.

ACKNOWLEDGEMENTS

This work is funded through NIH/NCI Cancer Center Support Grant P30 CA008748.