Dosimetric Impact of Direct CBCT-Based Dose Calculation Using the Ethos HyperSight Imaging System

Meiying Xing*, Beatriz Guevara*, Tessa Wrightson, Kenneth Gregg, Christian Petersen, Serageldin Attia, Theodore Arsenault, Gisele Pereira, Rojano Kashani, Lauren Henke, Alex Price

*Coauthor | University Hospitals / Case Western Reserve University

ABSTRACT

Purpose: The purpose of this study was to characterize the dosimetric consequences of direct CBCT dose calculation for abdominal stereotactic adaptive radiotherapy by comparing dose distributions calculated on simulation CT (simCT) versus HyperSight CBCT (HsCBCT). Emphasis was placed on quantifying direct dose discrepancies attributable to CBCT image artifacts and, HU accuracy in the largest cohort studied in literature to date.

Methods: Twenty abdominal cancer patients treated on Ethos 2.0 were evaluated, with five adaptive plans per patient calculated on HsCBCT. HU_{mean} and Artifact Index(AI) were assessed in artifact and non-artifact regions. HsCBCT images were target-registered to simCT, adaptive plans were transferred, and doses were recalculated on simCT. Target dose–volume histogram (DVH) metrics were compared using equivalence testing(ET) (±3%, 95% confidence intervals). Dose agreement was evaluated using 3D gamma analysis (1%/1mm, 10% threshold).

Results: Artifact regions exhibited notable HU_{mean} and AI differences with median values of 22.3(IQR:3.1-37.6) and 12.8(IQR:-32.3, 118.1), respectively. Moreover, ET demonstrated that AI is not clinically equivalent. However, PTV $D_{98\%}$, $D_{50\%}$, $D_{2\%}$, and $D_{0.1cc}$ calculated via ET displayed ±1.5% difference which indicates HU variability will not translate into clinically meaningful dose discrepancies. This is further supported by ±2.6% difference for External V_{33Gy} and D_{mean} of artifact regions confirming the absence of clinically significant dosimetric differences across 200 plans. Gamma analysis yielded average pass rates >95% , confirming dosimetric robustness despite HU variation.

Conclusion: Direct dose calculation on HyperSight CBCT demonstrated dosimetric equivalence to simCT-based calculations, with no clinically significant impact on dose distribution. These findings in a large cohort dataset indicate that HsCBCT imaging is suitable for accurate dose calculation, even in settings of high bowel gas artifact, in Ethos adaptive radiotherapy workflows.

KEY TAKEAWAY

HsCBCT HU variability from bowel gas did not produce clinically meaningful target or regional dose differences across a large 200-plan abdominal SBRT cohort.

CONTACT

Meiying Xing

University Hospitals / Case Western Reserve University

Department of Radiation Oncology

STUDY SNAPSHOT

20	200	50 Gy / 5 fx	95.6 ± 3.8%
pancreatic cancer patients	adaptive dose recalculations	Ethos adaptive SBRT	average 1% / 1 mm GPR

A) INNOVATION / IMPACT

- Largest patient cohort to date evaluating direct HyperSight CBCT dose calculation on Ethos 2.0 for abdominal stereotactic adaptive radiotherapy.
- Abdominal bowel gas presents a high-risk source of HU variability and dose-calculation uncertainty.
- By rigorously assessing dose agreement in an anatomically complex and artifact-prone setting, this work supports the clinical reliability of CBCT-based dose calculation in high-risk adaptive workflows.
- Emphasis was placed on quantifying direct dose discrepancies attributable to CBCT image artifacts and HU accuracy.

C) METHODS AND MATERIALS

- 20 patients with pancreatic malignancies treated with adaptive SBRT on Ethos to 50 Gy in 5 fractions; five HsCBCT adaptive fractions analyzed per patient.
- simCT datasets were registered to HsCBCTs; adaptive plans were transferred and doses were recalculated on both image sets.
- HU mean value and Artifact Index were recorded for artifact and non-artifact regions.
- Artifact contours were created by expanding duodenum, small bowel, large bowel, and stomach by 0.5 cm and cropping them within 3 cm of PTV33; non-artifact contour was created from the remaining ring excluding bone and metal expansions.
- Endpoints: PTV $D_{98\%}$, $D_{50\%}$, $D_{2\%}$, $D_{0.1cc}$; Dmean for artifact and non-artifact regions; and external V_{33Gy}.
- Clinical equivalence: paired-difference equivalence testing with ±3% margin and 95% CI; gamma 1%/1 mm, global normalization, 10% threshold.
- AI, HUmean, HU standard deviation, target DVH metrics, regional Dmean, and external V_{33Gy} were evaluated across all 200 plans.

B) ARTIFACT DEFINITION AND HU ASSESSMENT

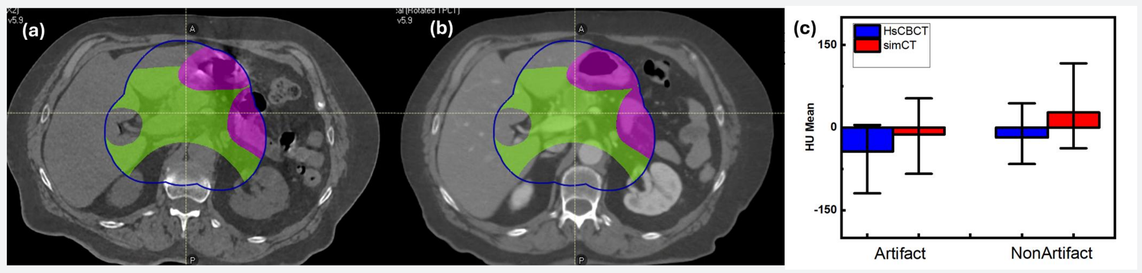

Fig. 1. Artifact regions (red) and non-artifact regions (green) are defined on HsCBCT and simCT. Box-and-whisker plots summarize HU mean differences in artifact and non-artifact regions.

D) VOXEL-LEVEL AGREEMENT

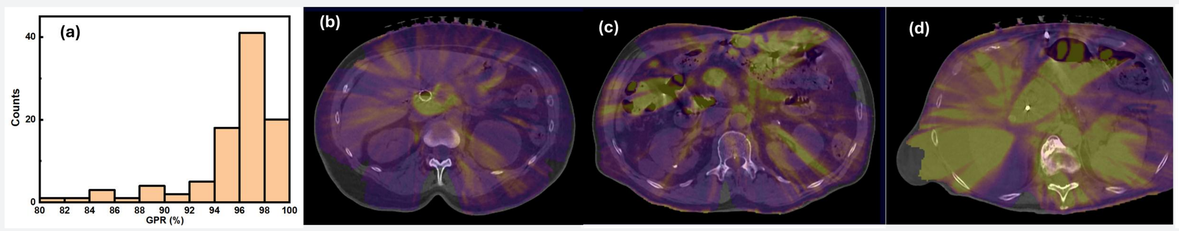

Fig. 3. Gamma pass-rate histogram and representative axial gamma overlays demonstrate strong voxel-level agreement. Across all plans, the restrictive 1%/1 mm gamma analysis with a 10% dose threshold yielded an average GPR of 95.6 ± 3.8%.

E) DOSE METRIC AGREEMENT

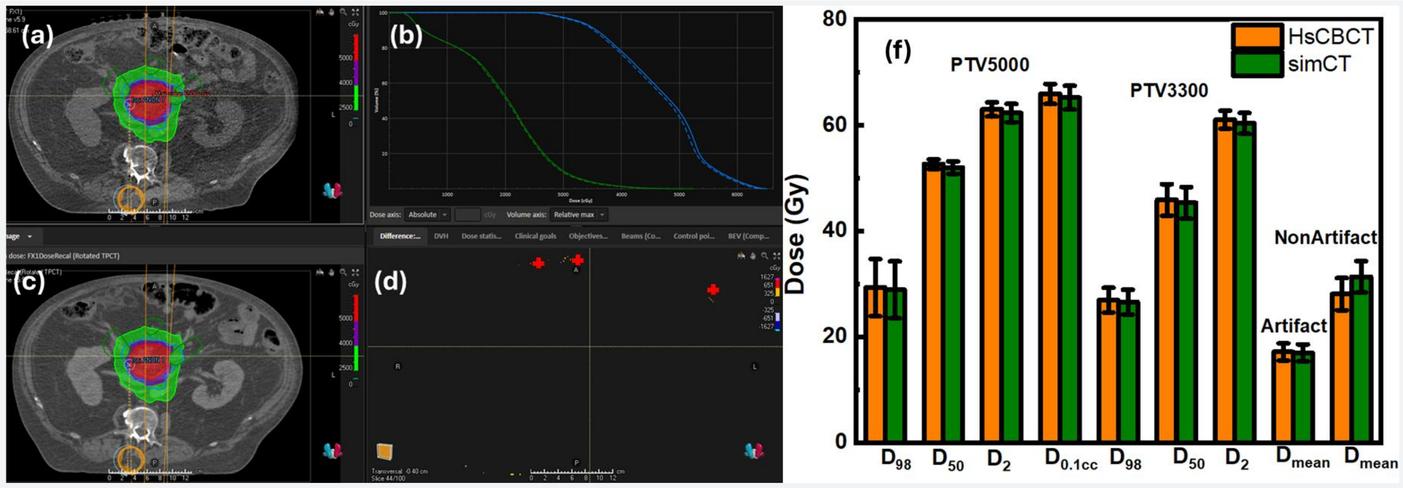

Fig. 2. Target (blue) and artifact (green) DVH metric discrepancies caused by differences in bowel gas between HsCBCT and simCT are small. The grouped bar chart summarizes target coverage and regional dose metrics across 200 plans.

F) RESULTS

- HUmean and Artifact Index showed significant modality differences driven by bowel gas artifact.
- HsCBCT vs simCT HUmean: Artifact −42.5 ± 32.2 vs −18.5 ± 31.7 ; NonArtifact 26.6 ± 36.2 vs 58.2 ± 16.1.
- Artifact Index: 167.0 ± 101.2 on HsCBCT and 122.4 ± 50.3 on simCT.
- ET confirmed clinically equivalent target and regional dose metrics; differences were within about ±2.6% for evaluated endpoints except the non-artifact Dmean nuance.
- Mean target differences: PTV50: $D_{98\%}$ 3.6%, $D_{50\%}$ 1.9%, $D_{0.1cc}$ 1.5%; PTV33: $D_{98\%}$ 3.8%, $D_{50\%}$ 2.2%.
- Gamma analysis: median GPR 99.6%; average GPR 95.6 ± 3.8%, range 81.7%–99.88%.
- Average External V_{33Gy} difference was 2.6 ± 1.6%; artifact and non-artifact Dmean differences were 1.2 ± 7.8% and 1.4 ± 16.9%.

G) DISCUSSION / CONCLUSIONS

- Bowel-gas artifacts caused measurable HUmean and AI differences, but these did not translate into clinically meaningful target or regional dose discrepancies.
- Equivalence testing confirmed clinically equivalent target and regional dose metrics between HsCBCT and simCT calculations.
- Strong gamma agreement supports reliable voxel-level dose consistency throughout the patient volume.
- Direct HyperSight CBCT dose calculation is suitable for accurate dose calculation in Ethos abdominal adaptive radiotherapy workflows, including cases with substantial bowel gas artifact.
- In this large cohort dataset, HsCBCT imaging was robust for direct dose calculation despite measurable HU and AI variation.