Dosimetric Validation of HyperSight-Based Online Adaptive Radiotherapy on a C-Arm Linac Using IROC Phantoms

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ABSTRACT

This study validated a HyperSight cone-beam CT (CBCT)-based online adaptive radiotherapy (oART) workflow on a conventional C-arm linear accelerator using Imaging and Radiation Oncology Core (IROC) anthropomorphic phantoms. Adaptive planning was performed directly on daily HyperSight CBCT images with contour propagation and plan re-optimization, and dosimetric accuracy was independently evaluated through the IROC credentialing process. HyperSight demonstrated sufficient image quality and Hounsfield Unit stability for direct dose calculation, with all adaptive treatments meeting IROC acceptance criteria and showing excellent agreement between planned and delivered dose distributions. These findings demonstrate the feasibility and dosimetric accuracy of HyperSight-based oART on a standard C-arm LINAC, supporting its potential as a clinically practical alternative to dedicated adaptive radiotherapy platforms.

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INTRODUCTION

Online adaptive radiotherapy (oART) enables treatment plans to be modified immediately before delivery to account for daily anatomical changes, improving target coverage while reducing dose to surrounding normal tissues. Recent advances in HyperSight cone-beam CT (CBCT) imaging have enabled high-quality volumetric images with sufficient Hounsfield Unit accuracy for direct dose calculation, making CBCT-based online adaptation on conventional C-arm linear accelerators feasible. Although a HyperSight-based oART workflow is not currently supported as a dedicated online solution by the vendor, the existing offline adaptive planning workflow can be performed in real time to generate and deliver an adapted treatment plan during the treatment session. This study validates the dosimetric accuracy and clinical feasibility of this HyperSight-based oART approach using independent IROC anthropomorphic phantom testing.

METHODS AND MATERIALS

An adaptive workflow was implemented on a TrueBeam linac using the Eclipse planning environment. The protocol utilizes contours and a preplan generated on a prior CT scan. Daily HyperSight CBCTs were registered to the prior CT, followed by contour propagation and plan re-optimization directly on the CBCT scan. Dosimetric validation was performed using IROC Head & Neck, Prostate, and Lung motion (gated at 40-60% exhale) phantoms. Each phantom was positioned with offsets, imaged, re-optimized, and irradiated. Accuracy was assessed via IROC's independent TLD and radiochromic film analysis. Verification plans were generated on reference CTs for comparison.

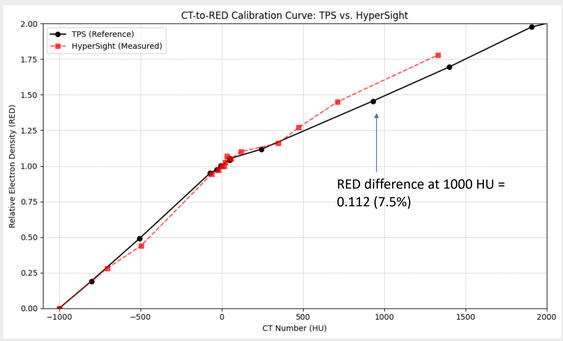
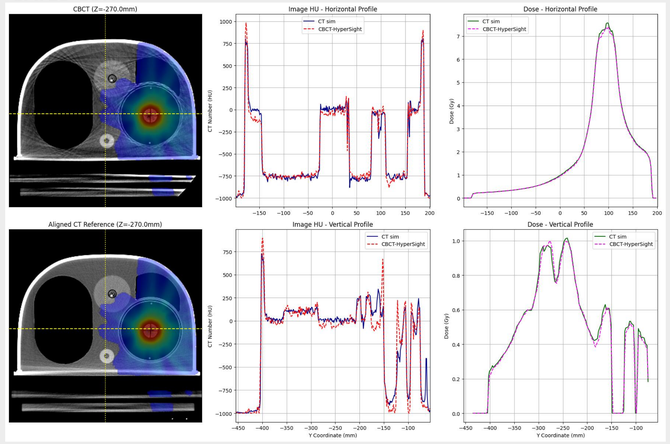


Figure 1. Electron density curve comparison between CT and HyperSight

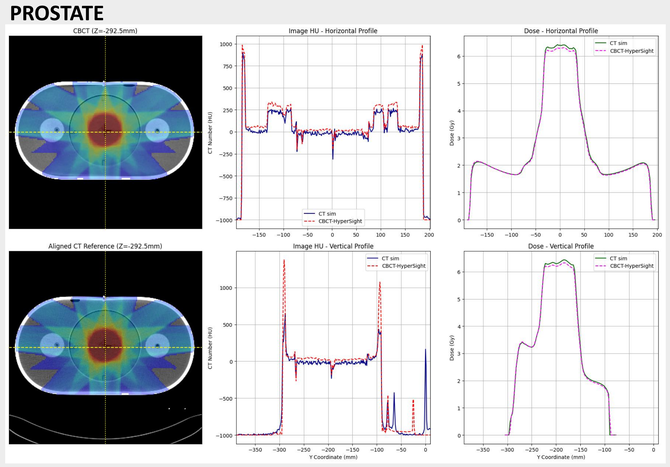
RESULTS

TLD point dose measurements and gamma pass rates across Lung, Head & Neck, and Prostate phantoms showed excellent agreement. Regarding imaging fidelity, the CT number to electron density calibration proved robust, showing deviations within 1.5% for the critical [-50, 50] HU soft-tissue window compared to the TPS. As shown in Figure 1, although minor localized HU differences existed, the resulting dose profiles matched the diagnostic plan almost perfectly, confirming the clinical safety of direct calculation.

GATED LUNG



PROSTATE



HN

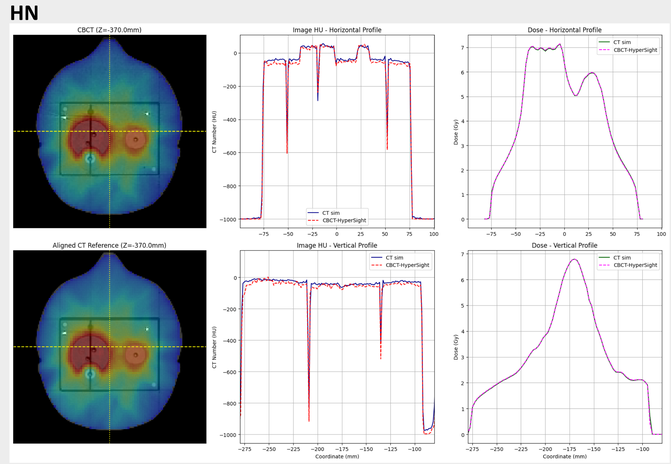


Figure 2. CT number and dose comparison between CT and HyperSight. Verification plans were generated on the reference CTs with the same monitor units (MUs).

Table 1. IROC phantom TLD and FILM results. TLD results are the ratio of measured to institutional dose. Gamma criteria are 7%/5mm for the lung, and 7%/4mm for the HN and Prostate.

IROC Lung Motion

TLD	Mea. vs Inst.
PTV_sup	0.96
PTV_inf	0.99
FILM	2D Gamma
Axial	100%
Coronal	100%
Sagittal	99%
Average	100%

IROC Prostate

TLD	Mea. vs Inst.
Cen. Prost. (Lt)	0.98
Cen. Prost. (Rt)	0.99
FILM	2D Gamma
Coronal	99%
Sagittal	100%

IROC HN

TLD	Mea. vs Inst.
Pri. PTV sup. ant.	0.98
Pri. PTV inf. ant.	0.98
Pri. PTV sup. post.	0.98
Pri. PTV inf. post.	0.98
Sec. PTV sup.	0.96
Sec. PTV inf.	0.96
FILM	2D Gamma
Axial	100%
Sagittal	100%

DISCUSSION

Online Adaptive Radiotherapy (oART) has traditionally been the exclusive domain of specialized platforms like Varian Ethos. We demonstrate that high-precision oART is achievable on a standard C-arm linear accelerator equipped with HyperSight technology. The system's superior image quality enables direct dose calculation on CBCT datasets without requiring complex synthetic CT generation, effectively democratizing adaptive therapy for clinics with existing infrastructure. Although this approach currently necessitates skilled manual intervention, this 'warm-start' workflow of modifying a pre-validated diagnostic CT plan offers a versatile and safe pathway to clinical implementation. With procedure times taking 40–60 minutes, the workflow proves comparable speed to dedicated adaptive systems. Future automation through scripting will further facilitate this process.

CONCLUSIONS

This study validates the dosimetric accuracy of a HyperSight-based online adaptive workflow on a standard C-arm linac. By enabling direct dose calculation on CBCT, this method opens the possibility of performing online adaptive RT on a C-arm LINAC, offering a clinically viable and versatile alternative to dedicated ring-gantry adaptive systems.

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