# Validation of An Offline Adaptive Radiotherapy Workflow on Halcyon 4.0 Using RayStation V11A

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2026 JULY 19–22 VANCOUVER, BC
JOINT AAPM | COMP MEETING

## ABSTRACT

**Purpose:** HyperSight CBCT (hCBCT) on Halcyon 4.0 provides image quality comparable to planning CT (pCT), supporting development of an offline adaptive radiotherapy (OART) workflow. This study evaluated the clinical feasibility of implementing an hCBCT-based OART workflow using RaySation v11A.

**Methods**: A multi-energy CT phantom was scanned using HyperSight CBCT Acuros protocols for head, thorax, and pelvis on a Halcyon 4.0 linac. HU-to-density relationships were derived per protocol and configured in RayStation v11A for hCBCT-based treatment planning. To validate the workflow, pCT and hCBCT images of an anthropomorphic head phantom were rigidly registered for contour propagation. A brain VMAT plan optimized on pCT was recalculated on hCBCT and evaluated using point, volumetric, and gamma metrics to assess dosimetric agreement. Retrospectively, the same workflow was applied to four clinical Halcyon brain VMAT patients. For each patient, six hCBCTs acquired at five-fraction intervals were replanned, and target and OAR doses were averaged and compared with the original clinical plans.

**Results**: HU-to-density calibrations showed small variations (max delta < 51 HU) across protocols. In phantom validation, the hCBCT plan had higher target coverage than the pCT plan, with increases of +0.7% for GTV D100% and +0.5% for PTV D95%. Optic chiasm D0.03cc increased by +0.5%, whereas brain stem D0.03cc decreased by 0.6%. Gamma values were 90.0% (1%/1mm), 99.5% (2%/1mm), and 100% (2%/2mm), indicating strong agreement between pCT and hCBCT plans. On average, clinical hCBCT plans exhibited higher target coverage (0.6%±0.4%, p=0.04) and higher PTV D0.03cc (+1.1%±0.2%, p = 0.006). OARs differences were minimal and not statistically significant.

**Conclusions**: A Halcyon-based OART workflow using RayStation v11A was demonstrated to be clinically feasible, with phantom validation confirming that dosimetry between pCT and hCBCT plans was closely matched. Application of this workflow in clinical patients further supported safe clinical implementation.

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## INTRODUCTION

Varian's HyperSight CBCT (hCBCT) offers significantly improved image quality over traditional CBCT regarding Hounsfield Unit (HU) fidelity and artifact reduction. Because its image quality has been proven comparable to a standard planning CT, hCBCT can be utilized for treatment planning. In our institute, Volumetric Modulated Arc Therapy (VMAT) plans for the Halcyon 4.0 linear accelerator are generated using the RayStation treatment planning system (TPS). With this infrastructure, exploring an adaptive radiotherapy workflow that pairs hCBCT with RayStation is desired. Therefore, the purpose of this study is to commission the Halcyon 4.0 hCBCT within RayStation (v11A) and validate a hCBCT/RayStation-based offline adaptive radiotherapy workflow.

## METHODS AND MATERIALS

- A multi-energy CT phantom was scanned on a Halcyon 4.0 linear accelerator using the hCBCT Acuos protocols for the head, thorax, and pelvis.
- HU per material density was averaged from three CT scans and was used to configure HU-to-density calibration curve in RayStation v11A for hCBCT-based treatment planning.
- An end-to-end (E2E) workflow validation was performed using an anthropomorphic head phantom through the following steps:
  1. **Baseline Planning**: A standard planning CT (pCT) of the head phantom was acquired, and a brain VMAT plan was generated using our institution's established optimization template.
  2. **Image Registration & Contour Propagation**: a hCBCT of the same phantom was acquired, followed by a rigid image registration between the hCBCT and pCT to propagate the clinical contours.
  3. **Plan Re-optimization**: The original plan parameters were transferred from the pCT to the hCBCT, where the plan was re-optimized using the identical template until all clinical dosimetric constraints were satisfied.
  4. **Delivery & Dosimetric Verification**: Patient-specific quality assurance (QA) was conducted, and the hCBCT-based VMAT plan was delivered to the head phantom, with absolute dose verified using inserted thermoluminescent dosimeters (TLDs).
- A retrospective study was conducted on four clinical Halcyon brain VMAT patients using the workflow established in the E2E phantom study. The baseline prescription consisted of a two-phase fractionation scheme: an initial phase of 46 Gy in 23 fractions followed by a boost phase of 14 Gy in 7 fractions.
  - For each patient, six hCBCT scans acquired across the treatment course at five-fraction intervals were selected for plan recalculation.
  - The recalculated plan dose were propagated back to the pCT to generate a cumulative plan sum. This cumulative adaptive dose distribution was dosimetrically compared against the original, clinically delivered plan.
  - The dosimetrics for evaluation include: $D_{95\%}$ of PTV, Dmax(0.03cc) of PTV, brain stem and optic chiasm.
  - The hCBCT-based adaptive plan was evaluated and compared against the original treatment plan.

## RESULTS

- hCBCT's HU shows maximum variation of 51HU across three clinically used protocols
- E2E phantom study demonstrated that plan on hCBCT is within 1% difference compared to plan on pCT regarding to GTV $D_{100\%}$, PTV $D_{95\%}$, D0.03cc of Optic Chiasm and brain stem.
- Retrospective study of four patient brain VAMT plans shows that plan recalculated on hCBCT is 0.6%±0.4% and 1.1%±0.2% higher than original plan in PTV $D_{95\%}$ and D0.03cc, respectively; for OARs (optic chiasm and brain stem), the difference is statistically insignificant.
- Reoptimized brain VMAT plans on hCBCT met all clinical dosimetric constraints, with MU differences of less than 2% compared to the original plans.

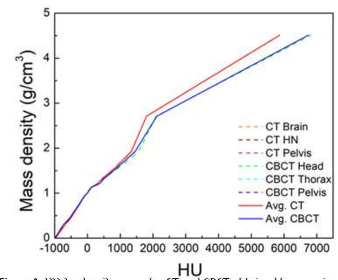


Figure 1. HU-to-density curve for CT and CBCT obtained by scanning a multi-energy CT phantom with three protocols.

Figure 2. A VMAT plan on a head phantom was calculated on CT (upper left) and HyperSight CBCT (lower left). Both calculated plans were compared by DVH curves (upper right. CT: solid lines, CBCT: dash lines) and clinic dosimetric criteria (lower right).

| Plan on pCT vs hCBCT | Plan on CT | Plan re-calc. on CBCT | Plan re-opt. on CBCT |
|---|---|---|---|
| GTV (D100% >6000cGy) | 6013 | 6054 | 6017 |
| PTV (D95% >6000cGy) | 96.52 | 98.68 | 96.66 |
| PTV (Dmax at 0.03cc) | 6196 | 6216 | 6206 |
| Brain Stem (D0.03cc) | 2288 | 2274 | 3250 |
| Optic Chiasm (D0.03cc) | 2019 | 2028 | 2558 |
| MU | 148.4 /166.7 | 148.4 /166.7 | 155.4 / 164.4 |
| Total MU | 315.1 | 315.1 | 319.8 |

Table 1. Dosimetric comparison between the original plan recalculated on the rigidly registered hCBCT (middle column), the re-optimized hCBCT plan (right column), and the baseline plan on CT (left column).

| TLDs | Calculation (cGy) | Measurement (cGy) | Diff. (%) |
|---|---|---|---|
| Medial Anterior | 209.2 | 209.6 | 0.2% |
| Left Anterior | 164.1 | 164.0 | -0.1% |
| Ileft Posterior | 108.8 | 104.5 | -4.0% |

Table 2. E2E study result: in vivo dosimetric validation of hCBCT-based plan on an anthropomorphic head phantom.

## RESULTS

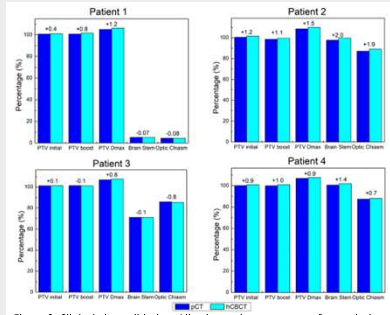


Figure 3. Clinical plan validation. All units are in percentage of prescription dose. Plan DVH evaluation criteria is as follows, PTV initial: D95% > 4600 cGy. PTV boost: D95%> 1400 cGy. PTV Dmax: D0.03cc < 6600 cGy. Brain stem Dmax: D0.03cc <5900cGy. Optic chiasm Dmax: D0.03cc <5900cGy.

## DISCUSSION

- Dose discrepancies between the pCT- and hCBCT-based plans may be attributed to differences in the field of view (FOV) between the two imaging modalities.
- Due to the smaller FOV of the hCBCT compared to the planning CT (pCT), OAR contours may be truncated. This requires manual contour modifications and adjustments to the plan optimization template, ultimately increasing the clinic workload for OART.
- Further work is required to improve the efficiency and maintain plan quality for more complex anatomy such as abdomen and Head&Neck (figure 4).

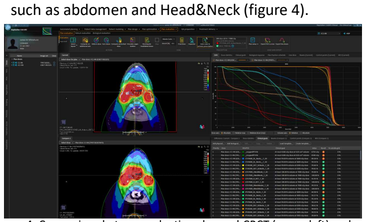

Figure 4. Comparison between adaptive plan on hCBCT (upper left) and on pCT (lower left). Both calculated plans were compared by DVH curves (upper right. CT: solid lines, CBCT: dash lines) and clinic dosimetric criteria (lower right).

## CONCLUSIONS

A Halcyon-based OART workflow using RayStation v11A was demonstrated to be clinically feasible, with phantom validation confirming that dosimetry between pCT and hCBCT plans was closely matched. Extending the RayStation-based OART to Halcyon also enables a unified environment across photon and proton services, supporting inter-modality and inter-clinic patient transfer.

## REFERENCES

1. Olberg S, McClatchy DM, Foote C, Yan S, Pursley J. Commissioning a standalone adaptive radiotherapy linac in a multi-vendor environment. J Appl Clin Med Phys. 2025;26:e70033.
2. Nelson N, Oare C, Nelson G, Martin T, Huang J, Zhao H. Feasibility of HyperSight CBCT for adaptive radiation therapy: A phantom benchmark study of dose calculation accuracy and delivery verification on the Halcyon. J Appl Clin Med Phys. 2025 Sep; 26(9).