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

Automated Workflow for Rapid VMAT Plan Migration Across Linac Geometries Without Manual Re-Planning

Christian De Caro, PhD; Jack Neylon, PhD
University of California, Los Angeles

KEY TAKEAWAYS

- **Problem**: Unplanned linac downtime requires rapid VMAT plan migration. Manual replanning is prohibitively slow, often resulting in patients missing their daily treatment fraction.
- **Gap**: Geometric leaf mapping alone fails for complex anatomy when transferring between mismatched MLCs.
- **Solution**: A practical, automated workflow utilizing an ESAPI leaf interpolation script, adaptable across various linac platforms, followed by MR4 reoptimization without manual intervention.
- **Outcome**: Fully recovered target coverage and restored original conformity while matching original OAR constraints, generating a ready to review plan in 5 to 10 minutes.
- **Impact**: Successfully deployed for a live clinical patient, adapting the plan across clinic sites and hardware to ensure immediate treatment continuity, and currently in use in the clinic.

PURPOSE

Unplanned linac downtime necessitates rapid transfer of VMAT plans to backup machines. Without matched machines, manual re-planning is labor-intensive, prohibitively slow, and often infeasible to complete in time to prevent patients from missing that day's scheduled treatment fraction. Prior methods relying on geometric leaf mapping often fail when transferring between different MLC models or beam profiles. This study validates a generalizable workflow, currently in active clinical use at our institution, that augments mathematical leaf interpolation to fully adapt plans to new machine constraints across linac platforms without manual re-planning.

METHODS AND MATERIALS

An in-house ESAPI script was written to map leaf positions across varying MLC geometries. For this validation, the script performed linear interpolation to map leaf positions from High-Definition (2.5 mm) to Standard (5 mm) MLC linacs.

Following geometric transfer, plans underwent a final fine-tuning re-optimization stage (MR4, Eclipse PO 15.6) using original objectives with no manual re-tuning.

The workflow was tested on five prostate cases and one complex Oropharynx challenge case (normalized to mandible constraints). Performance for the prostate cohort was evaluated using Global Max Dose, Target Coverage, and standard metrics calculated via ClearCheck: ICRU Homogeneity Index (HI), RTOG Conformity Index (CI), and Paddick Gradient Index (GI).

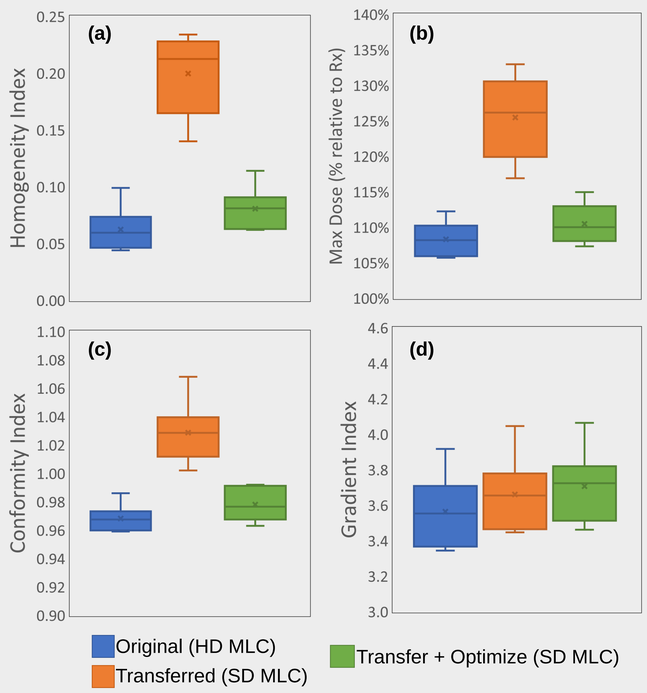


Figure 1. Dosimetric comparison of VMAT plan transfer for a Prostate cohort (N=5). **(a)** Homogeneity Index (HI), **(b)** Global Max Dose, **(c)** Conformity Index (CI), and **(d)** Gradient Index (GI). The "Direct Transfer" (Orange) introduces significant degradation in plan quality compared to the Original HD-MLC baseline (Blue). The proposed MR4 optimization workflow (Green) successfully restores Conformity to baseline levels (paired 2-sided t-test p>0.05), while the HI, GI, and max dose increases reflect the physical limitation of the standard 5mm leaf width. Whiskers extend to extent of data.

RESULTS

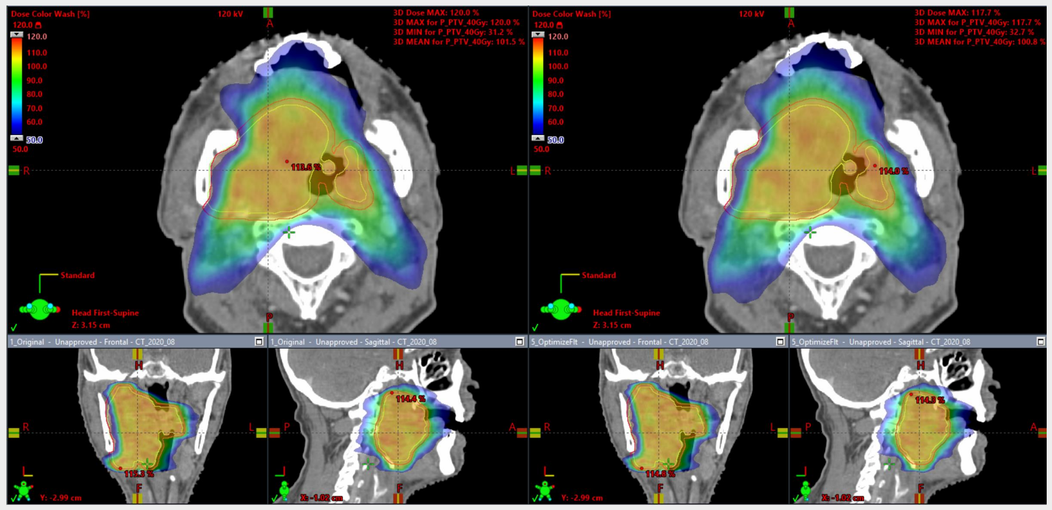
Geometric interpolation alone resulted in severe dosimetric failure. In the Oropharynx case, PTV and GTV coverage (V100%) collapsed from 82.6% and 83.7% (Original) to 11.9% and 14.6% (Direct Transfer) due to the inability of mapped leaves to navigate the OAR interface.

However, MR4 optimization recovered coverage to 81.3% and 83.2%, matching the HD-MLC baseline, while maintaining critical OAR doses within a few percent of original values throughout the DVH (Figures 2 & 3).

Similarly, for the Prostate cohort (Figure 1), the optimizer restored conformity to baseline levels ($p = 0.083$), correcting the significant degradation observed in the direct transfer. While the Gradient Index increased by 4% due to coarser leaf resolution, Global Max Dose and HI remained clinically acceptable, showing deviations of 2% and 0.018, respectively, a marked improvement over the 16% and 0.14 increases seen in the direct transfer.

Furthermore, this workflow was successfully translated to live clinical use to transfer a patient plan across disparate clinic sites and hardware types. By consistently generating a ready to review adapted plan in 5 to 10 minutes of computational time, this rapid adaptation facilitated immediate treatment continuity and successfully prevented a missed treatment fraction.

Figure 2. Dose distribution comparison for the Oropharynx challenge case. The original High Definition 2.5 mm MLC plan (left) is compared to the adapted Standard 5 mm MLC plan (right) following ESAPI leaf interpolation and MR4 reoptimization. The automated workflow successfully restores complex target conformity and strict mandible sparing despite the coarser leaf resolution.



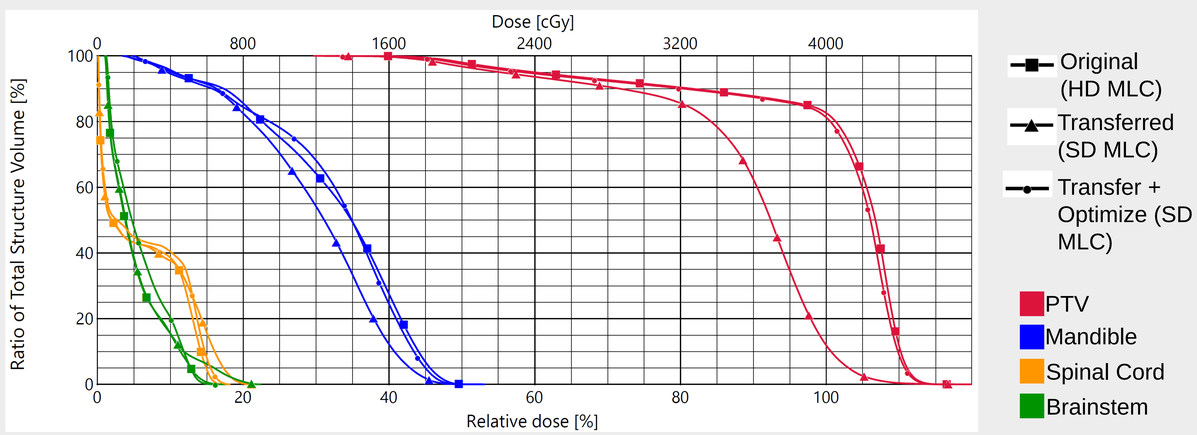


Figure 3. DVH of a complex Oropharynx case, normalized to fixed Mandible max dose. The Direct Transfer (triangle) results in substantial target coverage loss vs. the HD-MLC Baseline (solid) and simultaneously exceeds brainstem and cord constraints. MR4 Optimization (circle) effectively recovers coverage while maintaining similar OAR constraints.

CONCLUSIONS & FUTURE WORK

While geometric leaf mapping provides a starting point, it is dosimetrically insufficient for complex transfers between mismatched linacs. The addition of MR4 optimization is critical, effectively resolving discrepancies in MLC geometry and beam profiles to ensure safe, high quality treatment continuity during machine downtime across a diverse clinical fleet.

To further expand this clinical tool, future work will focus on:

- Varian Ethos Compatibility: Expanding the ESAPI interpolation script to accommodate the stacked, dual layer MLC geometry of the Ethos and Halcyon platforms.
- Reciprocal Transfers: Investigating the inverse pathway (Standard 5 mm MLC to High Definition 2.5 mm MLC). Because a 2 to 1 leaf mapping should theoretically preserve the exact initial dosimetry, we aim to evaluate if subsequent MR4 optimization can leverage the finer leaf resolution to produce a final plan superior to the original.

REFERENCES

1. 1. Afsharpour H, Nielsen M, Jensen M, et al. *A feasibility study of "plan transformation": A novel workaround enabling patient transfer between different Varian machines*. Physica Medica. 2021;91:13-17. doi:10.1016/j.ejmp.2021.10.0022.
2. French SB, Bhagroo S, Nazareth DP, Podgorsak MB. *Adapting VMAT plans optimized for an HD 120 MLC for delivery with a Millennium MLC*. J Applied Clin Med Phys. 2017;18(5):143-151. doi:10.1002/acm2.12134