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iADAPT Boost: Dosimetric Benefits of Hybrid CT-Guided Adaptive Radiotherapy for Pelvic Malignancies

Antonia Kubiatowicz, PhD,[1,2], Cindy Hancox, PhD[1,2], David (Bo) McClatchy, PhD[1,2], Jonathan Leeman, MD[1,2], Sarah Quirk, PhD[1,2], Hesham Elhalawani, MD[1,2]
[1]Mass General Brigham Cancer Institute, [2]Harvard Medical School

INTRODUCTION

CT-based online adaptive radiotherapy (CT-ART) enables real-time on-couch treatment adaptation accounting for anatomic changes such as filling, respiration, and peristalsis, while maintaining dose delivery consistency. Due to resource constraints, many centers reserve ART for ultra-hypofractionated courses; however, many moderately or conventionally fractionated radiation treatments could benefit from CT-ART. A resource-efficient strategy is a hybrid approach combining conventional image-guided radiotherapy with an adaptive cone-down boost, allowing organ-at-risk sparing as tolerance limits are approached.

METHODS AND MATERIALS

Eight patients with pelvic malignancies were evaluated. Five cases with cone-beam CT (CBCT) imaging were retrospectively simulated using the Ethos 2.0 emulator, and three patients were treated prospectively using the same hybrid workflow on a clinical Ethos system. The hybrid treatment consisted of conventional IGRT for initial fractions, followed by daily CT-ART boost fractions. For each adaptive fraction, daily anatomy was recontoured on CBCT, and AI-generated auto-segmented contours were reviewed and edited by the attending physician. Two plans were generated per fraction: a scheduled plan (original plan recalculated on daily anatomy) and an adapted plan reoptimized on daily anatomy to maintain target coverage while reducing OAR dose. Standardized Ethos planning directive templates ensured consistent target objectives and OAR prioritization. Dose accumulation and dosimetric comparisons were performed in MIM software. Endpoints included clinically relevant dose-volume metrics for bowel, bladder, rectum, testes, femoral heads, and spinal structures.

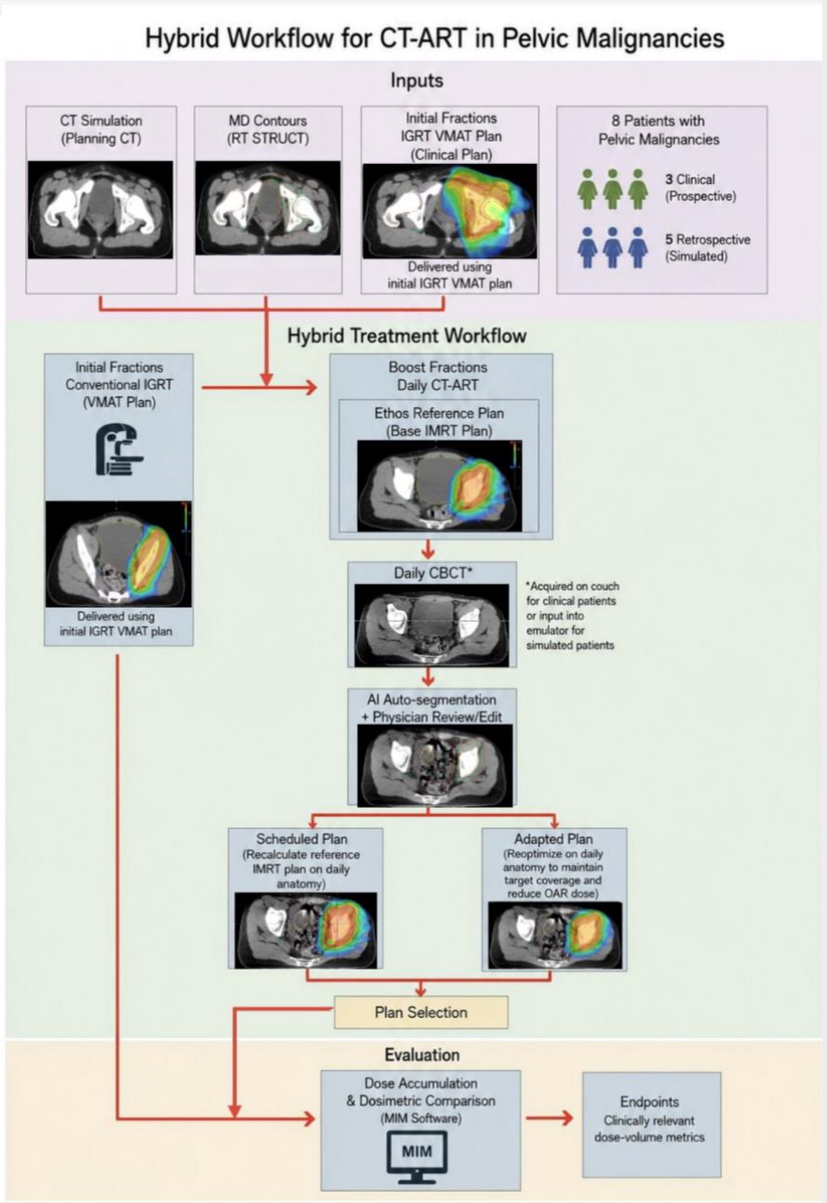

Figure 1: Workflow diagram

RESULTS

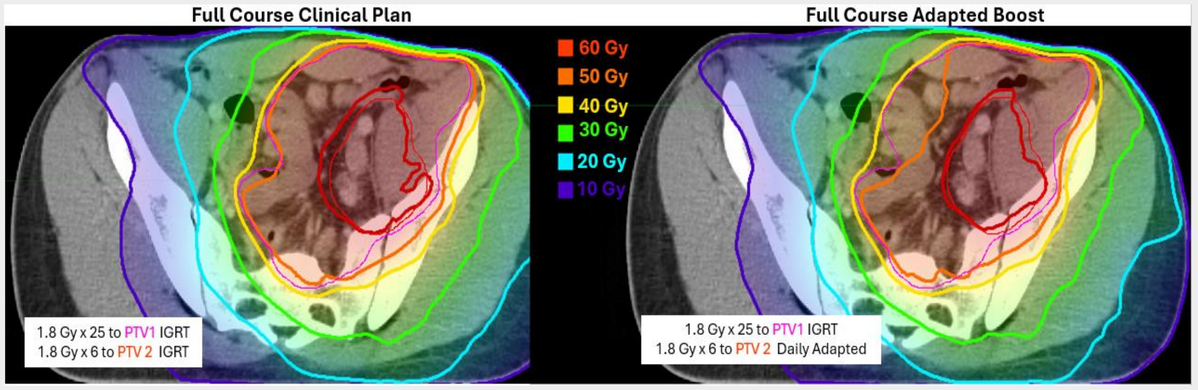

Figure 2: Demonstration of increased normal tissue sparing from the daily adapted boost plus initial clinical plan compared to the clinically delivered sum of plans in an example patient. A representative slice of each plan sum shows coverage was maintained in both plans while isodose lines are carved around critical organs in the adaptive methodology (right) compared to what was clinically delivered (left)

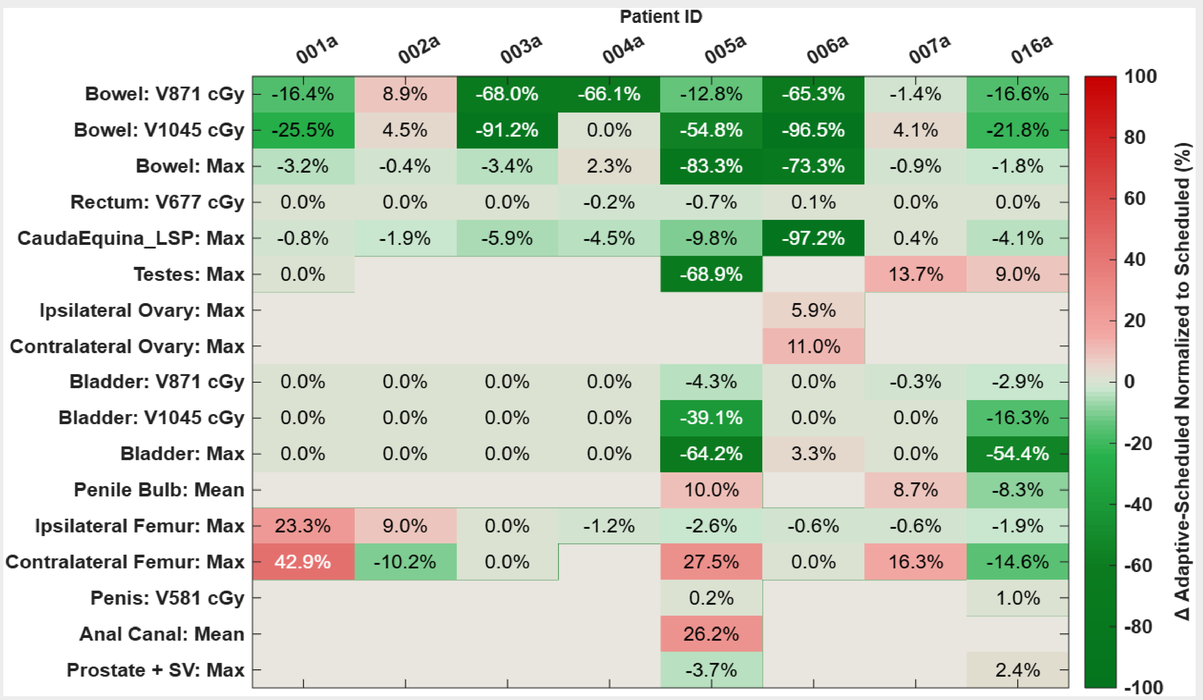

Figure 3: Average percent change in each OAR metric for each subject. Values are the average of all fractions for a given subject. Across all subjects, equivalent or better coverage on all targets was maintained.

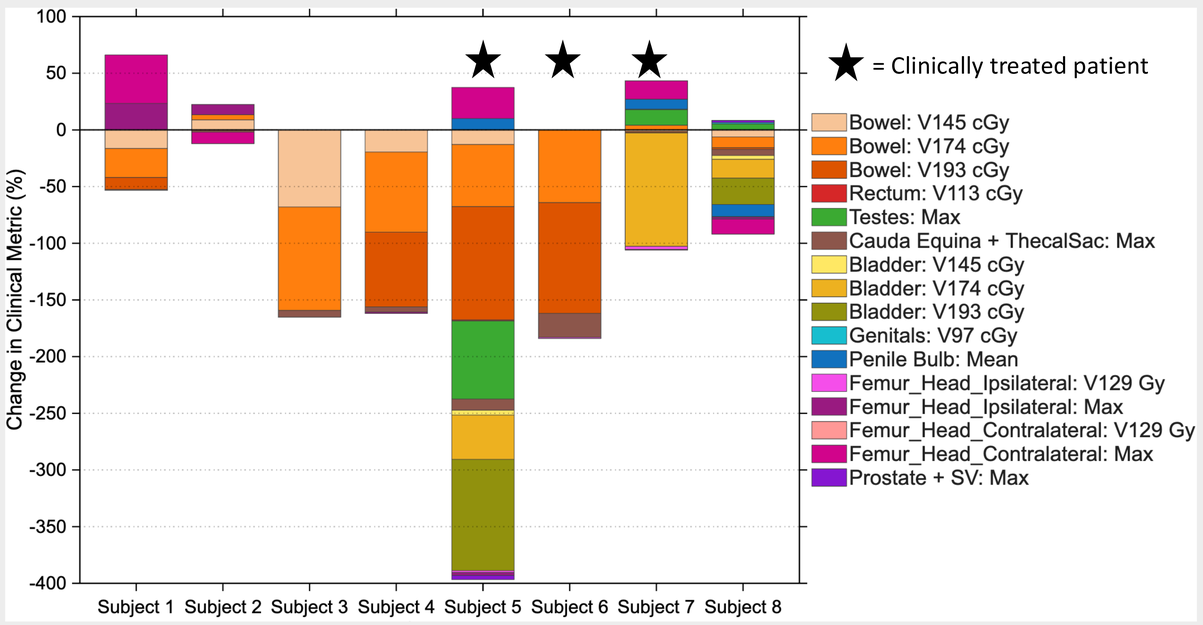

Figure 4: Patient-specific benefit from daily adaptive showing the trade off per patient made in the adaptive re-optimization. Each stacked bar is a different patient showing the change in each metric analyzed between the daily adaptive and daily SOC plans. Negative values indicate the adaptive plan spared the organ at risk more than the scheduled plan while positive values indicate the OAR was better spared in the scheduled plan. Subjects 4, 5, and 6 were clinically treated while remaining subjects were retrospectively analyzed.

DISCUSSION

This work introduces a pragmatic hybrid paradigm that integrates conventional IGRT with a selectively deployed CT-guided online adaptive boost, extending the benefits of adaptive radiotherapy. Rather than committing full adaptive resources to every fraction, this approach innovatively concentrates adaptation during the cone-down phase—when target volumes are smaller, anatomy is more variable, and the opportunity for organ-at-risk sparing is greatest. The use of standardized planning directives, AI-assisted contouring with physician oversight, and dose accumulation across fractions demonstrates a reproducible, scalable workflow that balances dosimetric gains with clinical feasibility. Clinically, it achieves consistent and meaningful reductions in bowel, bladder, and gonadal dose while maintaining target coverage. Operationally, it lowers the barrier to adaptive implementation by reducing time and staffing demands compared with full-course daily adaptation, making CT-ART accessible to a broader range of patients and practices. Together, these findings support hybrid CT-ART as a high-value model for expanding adaptive radiotherapy into routine pelvic cancer care, with the potential to improve patient quality of life without disproportionate resource utilization.

CONCLUSIONS

Hybrid sequential CT-ART provides meaningful OAR sparing during pelvic boost phases while preserving target coverage. This resource-efficient strategy extends adaptive benefits beyond ultra-hypofractionated regimens while minimizing clinical resource burden and supports broader clinical implementation.

CONTACT

Antonia Kubiatowicz, PhD
Mass General Brigham
akubiatowicz@bwh.harvard.edu

HARVARD MEDICAL SCHOOL
Mass General Brigham Cancer Institute