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Making Adaptive Radiotherapy Routine: A High-Throughput Adaptive–IGRT Clinical Workflow

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INTRODUCTION

Weekly or triggered online adaptive radiotherapy has not been widely adopted in clinical practice because of the time and resource demands. Although the Ethos platform enables CBCT-based online adaptive radiotherapy, daily adaptation may be unnecessary for treatment sites with gradual anatomical changes. This work describes the development and clinical implementation of a high-throughput online adaptive–IGRT workflow using the Ethos platform, in which adaptive replanning is performed weekly. The resulting adaptive plan is converted into a non-adaptive IGRT plan for subsequent fractions until the next adaptive session. The workflow is designed to maximize efficiency in a high-volume clinical environment.

METHODS AND MATERIALS

The workflow comprises three components: Adaptive Simulation, Adaptive-to-IGRT Plan Conversion, and Patient Scheduling. For initial adaptive treatments, HyperSight CBCT images and updated structures are acquired. Fiducial markers coinciding with simulation skin tattoos denote simulation isocenter coordinates during plan conversion. Adaptive-to-IGRT plan conversion is performed in the Ethos treatment planning system by importing adaptive CBCT images, structures, and plans, then switching to IGRT mode. Physics plan checks verify image accuracy, plan integrity, and monitor unit consistency. Adaptive and IGRT fractions are scheduled in ARIA, and a departmental web-based dashboard provides real-time visibility into adaptive scheduling.

RESULTS

Implementation of the Adaptive–IGRT workflow resulted in a marked increase in adaptive treatment capacity, with average daily adaptive patient volume rising from 6 to 17 patients. A total of 79 adaptive-to-IGRT plan conversions were completed for 15 patients across lung, rectum, esophagus, pancreas, and cervix treatment sites. Mean adaptive-to-IGRT plan conversion time ranged from 25 to 30 minutes, with physics plan check times of 15 to 25 minutes, demonstrating a clinical workload compatible with high-throughput practice. Standardized workflow checklists (Figure 1) mitigated key failure modes related to online imaging, patient scheduling, and communication gaps while real-time schedule visualization via a departmental dashboard (Figure 2) improved coordination and supported scalable clinical implementation.

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DISCUSSION

Conventional offline adaptive radiotherapy has remained difficult to operationalize because repeat imaging, contour revision, replanning, plan transfer, quality assurance, and scheduling must often be coordinated across multiple systems and clinical teams. These labor-intensive steps can delay availability of the revised plan. The presented adaptive-to-IGRT workflow represents a next-generation approach by reusing a clinically reviewed online adaptive plan rather than initiating a separate replanning process from the beginning. This creates a practical bridge between daily online adaptation and conventional IGRT, allowing adaptation frequency to be matched to the rate of anatomical change, improving treatment-room efficiency and scalability. **The increase in adaptive volume from 6 to 17 patients per day demonstrates that this model can support adaptive radiotherapy in a high-volume clinic. The observed failure modes were predominantly operational, highlighting that successful adaptive implementation is not solely a planning problem, but also a systems-engineering and communication challenge. Standardized conversion, independent physics review, role-specific checklists, and centralized scheduling visibility therefore serve as essential safety controls.** Further automation of plan conversion and verification could make weekly or triggered adaptation a routine treatment strategy for patients with gradual anatomical changes.

CONCLUSIONS

This high-throughput adaptive–IGRT workflow enables sustainable integration of weekly or triggered adaptive radiotherapy into busy clinical environments, facilitating routine adaptive practice without excessive clinical burden.

Figure 1. Adaptive–IGRT plan conversion workflow. Abbreviations: IGRT, image-guided radiotherapy; FOV, field of view; TPS, treatment planning system.

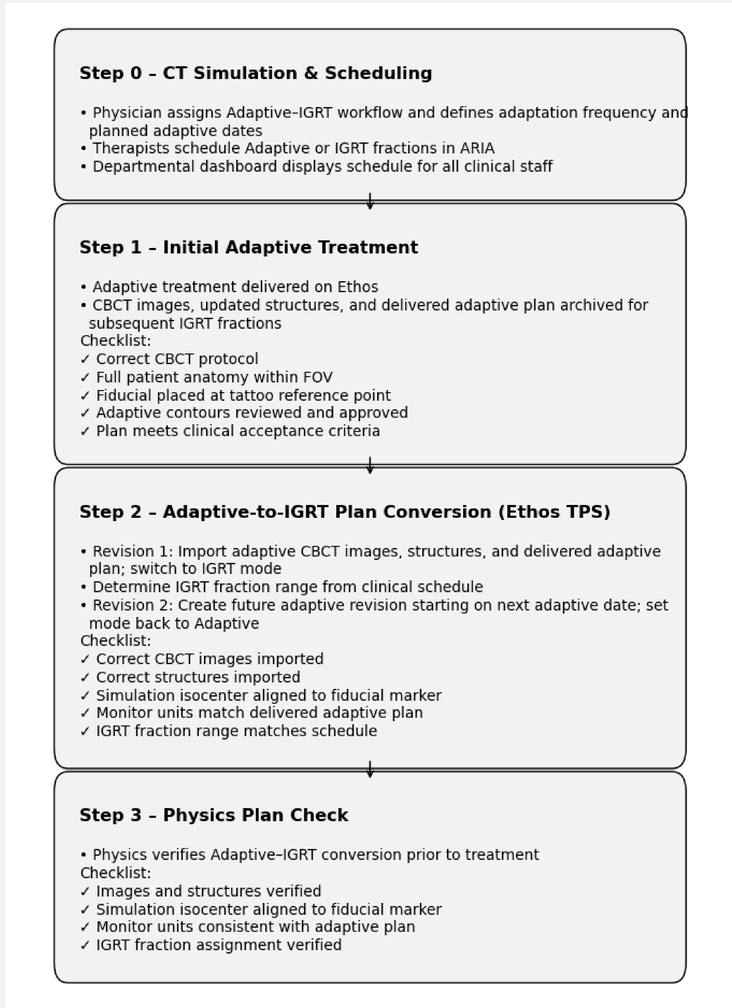
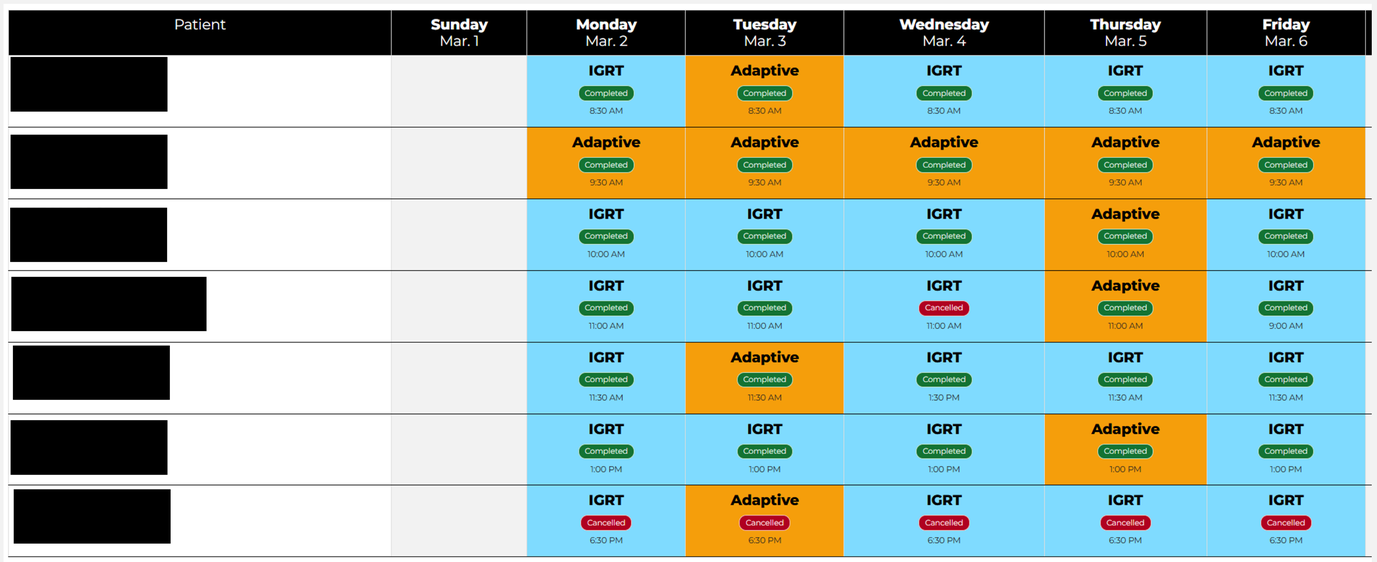


Figure 2. Departmental web-based dashboard developed to visualize patient schedules in real time for resource allocation and adaptive-to-IGRT plan conversion coordination.



Patient	Sunday Mar. 1	Monday Mar. 2	Tuesday Mar. 3	Wednesday Mar. 4	Thursday Mar. 5	Friday Mar. 6
[redacted]		IGRT Completed 8:30 AM	Adaptive Completed 8:30 AM	IGRT Completed 8:30 AM	IGRT Completed 8:30 AM	IGRT Completed 8:30 AM
[redacted]		Adaptive Completed 9:30 AM	Adaptive Completed 9:30 AM	Adaptive Completed 9:30 AM	Adaptive Completed 9:30 AM	Adaptive Completed 9:30 AM
[redacted]		IGRT Completed 10:00 AM	IGRT Completed 10:00 AM	IGRT Completed 10:00 AM	Adaptive Completed 10:00 AM	IGRT Completed 10:00 AM
[redacted]		IGRT Completed 11:00 AM	IGRT Completed 11:00 AM	IGRT Cancelled 11:00 AM	Adaptive Completed 11:00 AM	IGRT Completed 9:00 AM
[redacted]		IGRT Completed 11:30 AM	Adaptive Completed 11:30 AM	IGRT Completed 1:30 PM	IGRT Completed 11:30 AM	IGRT Completed 11:30 AM
[redacted]		IGRT Completed 1:00 PM	IGRT Completed 1:00 PM	IGRT Completed 1:00 PM	Adaptive Completed 1:00 PM	IGRT Completed 1:00 PM
[redacted]		IGRT Cancelled 6:30 PM	Adaptive Cancelled 6:30 PM	IGRT Cancelled 6:30 PM	IGRT Cancelled 6:30 PM	IGRT Cancelled 6:30 PM