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The impact of an Advanced Practice Radiation Therapist contouring for a CBCT-based adaptive radiotherapy program

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A B S T R A C T

We successfully implemented an APRT specializing in CBCT-guided online adaptive contouring. These data show statistical improvements in contouring time with APRT-led vs non-APRT led ART contouring, suggesting that an APRT specifically trained to manage the ART process may reduce physician workload and patient treatment time.

Introduction

Online adaptive radiation therapy (ART) allows for a patient's treatment plan to be adjusted to account for changes in the patient's anatomy-of-the-day via re-contouring and re-optimizing, all while the patient is on the treatment table [1,2]. ART has been demonstrated to widen the therapeutic index of radiotherapy in the treatment of head and neck [3], ultra-central thoracic [4,5], abdominal [6–9], and pelvic malignancies [10,11], amongst other disease types. However, ART is resource and time intensive, requiring therapists, physicists, and physicians to complete the multi-step re-planning process, which can result in end-to-end workflow times of up to 100 min [11,12].

In our high-volume ART clinic, physicians covering adaptive cases are often simultaneously staffing clinic, which can introduce delays into the ART process as physicians are required for new contour and plan approval. This can increase the burden of ART on the clinic staff and patients. To help manage this additional time requirement, an Advanced Practice Radiation Therapist (APRT) position [13] was created to specialize in CBCT guided adaptive contouring. An APRT demonstrates expert practice in a specialized area, working autonomously, taking on a leadership role in the development of RT services, and research associated with their specialty [13]. Herein we evaluated our institutional adaptive volume and timing data with and without the APRT to identify any potential workflow improvements that may have resulted from the implementation of the APRT.

Methods and materials

Adaptive workflow

The Ethos adaptive radiotherapy system (Varian, A Siemens Healthineers Company, Palo Alto, CA) (version 1.1) utilizes the Halcyon linear accelerator on a standalone treatment planning system (TPS) to perform CBCT-guided online adaptive treatments (CTgART). An overview of the online adaptive process can be seen in Fig. 1. This process starts with an initial CBCT. After image acquisition, the Influencer structures (anatomic structures that have a high likelihood of affecting the shape and position of the target) can either be auto-contoured using a convolution neural network-based artificial intelligence (AI) segmentation model, or deformably copied from the planning CT if no auto-segmentation model exists for that structure.[14,15] These structures can be edited before the target deformation. The Target Structure uses the influencers and the deformation of the sim CT to the CBCT to deform the target. The Edit Contours workspace then allows for rigid target alignment and OAR contouring (including non-influencer structures). Once contours have been edited, reviewed, and approved, the initial reference plan is recalculated on the anatomy-of-the-day (Scheduled Plan) and a new plan is optimized and calculated (Adapted Plan). The physician then selects the plan best suited for treatment based on OAR constraints and target coverage. If the adapted plan is chosen, cloud-based quality assurance (QA) using a third-party software is performed before the treatment. A verification CBCT is taken before treatment to ensure proper patient alignment after the adaptive process.

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Advanced Practice Radiation Therapist (APRT)

In our practice, the APRT is used as a physician extender and is specifically designated to cover adaptive treatments for the Ethos. Pre-treatment, the APRT will review the original physician approved contours from the simulation scan on a second computer. This will also be used as a reference, during the adaptive process, to help accurately align the target. An Adaptive Guidelines document is also reviewed that provides a detailed description of the area being treated, target description, relevant OARs, and any unique anatomical considerations that should be noted by the physician, physicist, or APRT. [16].

During treatment, the APRT evaluates the initial CBCT image quality to determine acceptability of the scan for contouring. Scans are repeated if of insufficient quality. The Influencer and Target Structure workspaces are passed over to get to the Edit Contours workspace, where the APRT will rigidly propagate and align the simulation target(s). This rigid propagation includes the original target volume drawn by the attending, and a 3cm contour ring structure, which is derived from the Planning Target Volume (PTV).[16] This is our standard workflow for all adaptive cases, the only exception being bladder treatments. After target alignment, the APRT will contour the necessary OARs within the propagated 3cm contour ring. RTTs will page the covering physician once contours are nearly completed. The APRT will then brief the covering physician on the patient, relaying any discrepancies with target alignment, due to patient setup or tumor growth, and/or any issues from previous fractions, like targets being modified. Target adjustments can only be made by the physician. The physician will check the alignment, review the contours, and make any adjustments to the target and/or OARs they feel are necessary. Every adaptive case must have the alignment and contours approved by a physician before proceeding to plan calculation.

APRT training and credentialing

Our institutional APRT training and credentialing requirements are found in Fig. 2. Prior to covering adaptive treatments, the APRT must complete training and credentialing. Training begins with observation to learn the clinical workflow and understand the overall machine concepts that are required for the adaptive process. Since OAR delineation is not a basic skill for RTTs in our department, contour training is required. Contour training begins offline with 20 example cases per disease site (e.g., head and neck, thorax, abdomen, and pelvis) being provided to learn and delineate relevant OAR anatomy. This contouring practice is done within our TPS and uses a combination of CT simulation images and CBCTs. The APRT will also have multiple one-on-one sessions with a physician to ask any questions, review at least half (i.e., 10) of the completed contours, and discuss the relevant anatomy frequently encountered in our clinic's CTgART treatments. Once offline contouring has been completed, the APRT begins contouring in a simulated environment. This simulated training focuses on target alignment, learning the system's unique contouring tools, and contouring OARs specifically within the contour ring. Ten patient datasets must be completed per disease site within a simulated workflow. These are then reviewed by a physician to evaluate accuracy, and a physicist to explain how these new contours can affect the dose distribution of the newly simulated treatment plan. After training and credentialing have been completed, the APRT will begin contouring adaptive cases under direct supervision of a physician for the first two weeks, with a minimum of 20 adaptive fractions of real-time contouring work.

Data collection and statistical analysis

Between October 2022 and July 2023, timing data was prospectively recorded for every adaptive patient treated on Ethos. All timing data were stratified depending on whether the APRT was present and contouring (APRT fraction) or if the APRT was absent and contouring was completed by the physician (non-APRT fraction). For consistency purposes, timing data were recorded at the start of each task and stopped when that task was completed. Data were collected for contouring, MD review, plan calculation, and plan review. Contouring time is defined as the time spent propagating the target, target alignment, and contouring the OARs within the Edit Contours workspace of the Ethos workflow, not including time waiting for physician arrival. MD review time is defined as the time the physician spent checking the alignment, reviewing the contours, and any adjustments made to the target and/or OARs they felt were necessary. For non-APRT fractions, it was assumed the entire time spent was dedicated to contouring. The overall adaptive process time is defined as the time between the initial CBCT and the pre-treatment CBCT. This includes image acquisition, contouring, MD review, plan optimization and calculation, plan review, and plan QA. Total treatment time is the total time the patient spent inside the treatment room.

With regard to the recorded contouring, adaptive process, and total time, a histogram evaluation was done and due to the number of samples used, a Shapiro-Wilk test was also completed on each grouping of time to test for normalcy of the data. Additionally, a normal and detrended Q-Q plot was assessed for normalcy. Data for all three groups were deemed to not be normally distributed so a non-parametric test was used. In considering all the data for every patient and fraction independently, an independent samples Mann-Whitney *U* test was used with a $p<0.05$ considered statistically significant. This test compared time between the APRT and non-APRT sessions regarding recorded times for contouring, adaptive process, and total time.

Seventeen of the 36 patients studied had all fraction as APRT fractions. The remaining 19 patients had at least one APRT fraction and at least one non-APRT fraction. This allowed for an additional statistical analysis to be completed, looking at the intra-patient comparisons between APRT and non-APRT fractions. All fractions contoured by each were averaged and then the two average times were compared. Structuring the data in this way allowed for a related samples Friedman test with a post hoc two-tailed Wilcoxon signed-ranks test to be conducted. A p-value less than 0.05 was considered statistically significant. Due to the increased risk of a type 1 error when averaging data, the comparison was also Bonferroni corrected. All analyses were performed using SPSS version 29.0 (SPSS, Chicago, IL).

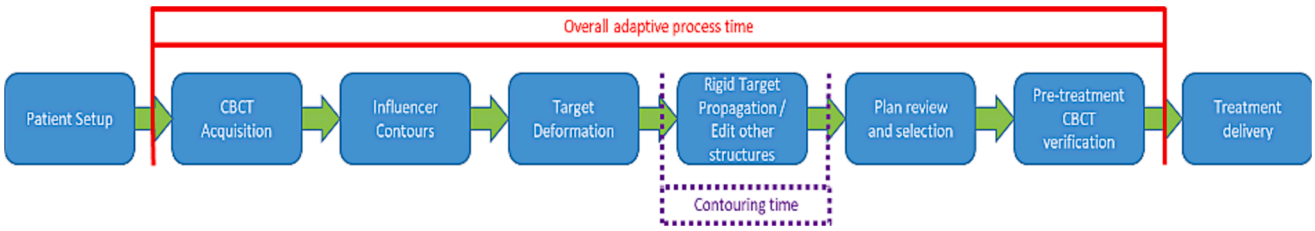

Fig. 1. CTgART workflow. For the purposes of this study, the online adaptive process time was recorded as from the start of initial CBCT acquisition to the start of verification CBCT. Contour time is defined as time spent on manual edits to structures. At our institution, that process starts after the Influencer and target deformation steps.

Learning Objective	Tasks	Number of cases	Outcome
Clinical Workflow	Simulations	5	Learn and understand aspects of simulation important to Ethos Adaptive
	Treatment Planning	5	General understanding of Ethos treatment planning
	Physics	3	Rigorous understanding of important chart checks for Ethos Adaptive cases and where pertinent documentation exist
	Adaptive Procedure	10	Understand general adaptive workflow and everyone's role in the adaptive process
Machine Concepts	Adaptive Guidelines		Can locate and understand the physician's adaptive guidelines
	Original Contours		Can locate and review the physician's original contours
	Identify surface guidance		Can setup and utilize the motion management system
	CBCT evaluation		Can assess Ethos CBCT for image artifacts/evaluate image quality for contouring
	Influencers		Can correctly identify, evaluate, and edit Influencers
	Target propagation		Can propagate and align targets accurately
Contour Training	OAR contouring in Eclipse	20 per treatment site (at least 10 reviewed by MD)	Competency for normal tissue delineation
	Ethos Emulator	10 per site (at least 5 reviewed by MD)	Competency for online contouring tools in a timely manner
Adaptive Process/ On-going training	Direct Supervision	20 fractions	Online contours completed and reviewed under direct supervision from a physician before working solo
	Assess improvement / Ongoing maintenance	12-20 cases per year per site	Observed improvement in contouring time and accuracy. Minimum of 12-20 cases done online per site otherwise refresher training for site is required

Fig. 2. Institutional APRT training and credentialing learning objectives and expected outcomes. Tasks include understanding the adaptive workflow, machine concepts, and contour practice on a total of at least 30 cases per anatomic site (20 for anatomy practice and 10 simulated adaptive cases). Each institution's adaptive program and "adaptor" positions will vary and training and credentialing programs should be developed for each institution's specific needs.

Results

Between October 2022 and July 2023, there were 183 total adaptive treatment sessions: 92 abdominal, 80 pelvic, and 11 thoracic (Fig. 3). Detailed contouring, adaptive process, and total treatment times are found in Fig. 4. The APRT was present for 136 sessions (47 non-APRT sessions). APRT contouring was performed by one APRT, and physician contouring was performed by seven physicians. When analyzing the total collective data, the average APRT contour time was 8 min for APRT and non-APRT contouring time was longer at 20 min ($p < 0.001$). There was no statistically significant difference in adaptive process and total treatment time. With an APRT contouring, the overall average for the

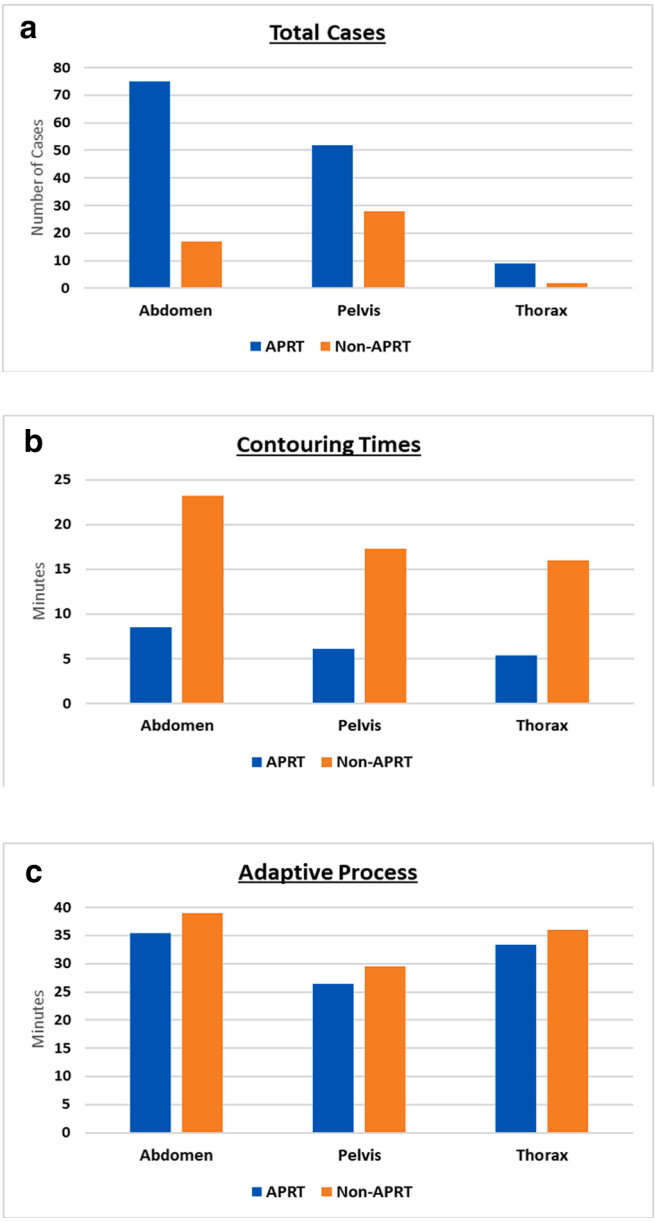

Fig. 3. Adaptive volume and contouring times. A: Contour site fractions; APRT v non-APRT. B: Contour time by disease site; APRT v non-APRT. C: Adaptive process time (initial scan to verification scan); APRT v non-APRT.

adaptive process took 31 min, while non-APRT sessions contour time took 33 min. Total treatment time was 48 min (APRT) and 49 min (non-APRT).

A separate analysis was done concerning the related samples test (intra-patient comparisons) where average times for the APRT and non-APRT were compared for the same patient. This showed that the APRT provided a statistically significant decrease in the amount of time required to contour ($p < 0.001$). It was also found that the total treatment time was reduced significantly by the APRT ($p < 0.05$). No statistically significant change was found in the adaptive time using the related samples test.

Discussion

In this study, the contouring time was 12 min faster when the APRT was contouring. However, we did not see the same time savings in the overall adaptive process and treatment time which is likely attributed to inefficiencies in our process. The APRT would typically wait until they had a minute or two left of contouring before paging the covering physician. Our data showed that on average it took the physician 5 min to arrive (Fig. 4) and additional time to review adaptive guidelines for the case and the APRT's contours. To become more efficient, the physician is now paged earlier in the contouring process so they can review adaptive guidelines and original contours while APRT contours are being completed. Interestingly, when looking at intra-patient comparisons, contouring time and total treatment time was statistically shorter for APRT fractions than non-APRT fractions, while the adaptive process was not significantly different. We hypothesize that the presence of an experienced therapist had an impact on not only contouring efficiency but also on patient setup and/or treatment delivery.

This same effect on total treatment time was likely not seen in the overall evaluation due to the variety of adaptive treatments across multiple disease sites included in the analysis. For example, pancreas SBRT cases, which take at least 45 min and typically over an hour, were evaluated alongside hypofractionated bladder treatments that were completed on average within 30 min per trial protocol. This variation can mask improvement in total treatment time among the entire population, while intra-patient analysis indicates improved treatment times with the APRT present.

Online ART has steadily become more widely available with multiple systems designed to allow for expedient ART workflows. In a high-volume clinic such as our own, over 250 patients are treated with ART each year [12]. The vast majority of these are high dose cases, five fractions or less, requiring physician presence for every fraction. Our department employs a "doc of the day (DOD)" coverage strategy for all adaptive cases, with generally two physicians assigned to cover adaptive treatments each day [16]. Other staff coverage models also exist, especially for more conventionally fractionated adaptive treatment schemes, where departments are working towards RTT only workflows [17,18]. A clear advantage of non-physician coverage models is that they provide the physician flexibility to focus on physician required tasks (i.e. new patient consults). However, given billing requirements in certain countries, such as the United States, that require physician approval of new plans prior to treatment, this may not always be feasible. An APRT role could create a new pathway for RTTs, allowing for growth and job satisfaction. By using an APRT as a physician extender, the APRT can assist with the tedious and time-consuming aspects of ART, thus, reducing the burden of ART on staff and resources.

Another advantage of an APRT-led model is improved communication for DOD coverage. While prescribing physicians are instructed to provide as much information as possible in an adaptive guideline document to facilitate DOD coverage, an APRT that is present at all treatment fractions can quickly summarize challenges and unique contouring or planning approaches that were implemented in earlier fractions by a different physician and physicist team. If ART continues to expand, especially to longer fractionation regimes, DOD coverage models may be unsustainable. An ART program requires significant upfront investments. However, by task shifting ART contouring to an APRT, we can provide physicians more time to conduct work that only they can do, similar to the non-physician coverage models, and meet the billing requirements, while still being able to deliver the same quality ART treatment. Each clinic and ART program will be unique and the APRT role should be determined at each institution. Training and credentialing programs should be developed with each institution's specific needs in mind.

A limitation of this study was the analysis of transition time for the physician. For APRT fractions, the physician was paged when contours were nearly complete. For non-APRT fractions, physicians were paged as the initial CBCT was being acquired. It is assumed that non-APRT fraction contouring time was entirely spent in the Edit Contours workspace, of the Ethos workflow, due to how we defined contour time. This would not include transition time in cases of physician delay to the machine due to conflicting responsibilities. Transition time had more of an effect

APRT (minutes)									
Site	# of Fractions	Contouring	Transition	MD Review	Calculation	Plan Review	Adaptive Process	Delivery Time	Total Time
Adrenal	20	5	5	2	7	1	28	20	50
Abdomen	31	8	7	2	8	2	33	19	52
Pancreas	24	14	5	3	9	2	41	26	66
Pelvis	52	6	5	3	4	2	26	10	36
Thorax	9	6	8	4	6	2	33	22	54
Total	**136**	**8**	**5**	**3**	**6**	**2**	**31**	**17**	**48**
MIN	1	1	1	2	1	12	4	16	
MAX	19	19	10	21	6	45	47	89	
MEDIAN	7	5	2	7	2	23	16	44	

Non-APRT (minutes)									
Site	# of Fractions	Contouring	Transition	MD Review	Calculation	Plan Review	Adaptive Process	Delivery Time	Total Time
Adrenal	2	20	-	-	6	3	35	22	56
Abdomen	9	22	-	-	7	2	38	21	59
Pancreas	6	26	-	-	8	2	42	25	67
Pelvis	28	17	-	-	3	2	30	12	41
Thorax	2	16	-	-	6	2	36	19	55
Total	**47**	**20**	**-**	**-**	**5**	**2**	**33**	**16**	**49**
MIN	7	-	-	2	1	15	4	26	
MAX	38	-	-	12	4	56	34	82	
MEDIAN	13	-	-	4	2	32	17	48	

Fig. 4. Detailed representation of online adaptive times in minutes recorded for Top) APRT fractions and Bottom) non-APRT fractions. Transition time is time between APRT completing contours and arrival of covering physician.

on the adaptive process time, which could possibly explain why we did not see a significant difference in our analysis. An additional limitation of this study is that the physician contours were performed by any one of seven physicians, and therefore there may be some variation in contouring speed and overall adaptive efficiency between physician to physician compared to APRT contours which were all done by one APRT.

APRT contouring accuracy and quality was not evaluated along with timing. Once the APRT was trained per the training regimen delineated in the Methods, it was assumed that contouring quality was sufficient for integration into the departmental ART clinical workflow. The DOD would evaluate the APRT contours as a part of their workflow, but quality was not formally assessed by the covering physician at that time. Anecdotally, physicians tend to make minimal changes to APRT OAR contours, as reflected in the low MD review times demonstrated in this paper. Future work should include evaluating the accuracy of APRT contouring and potential time savings of presenting the covering physician with the contours and adapted plan at the same time to further improve ART treatment efficiency.

Conclusion

Herein we demonstrated the successful implementation of an APRT specialized in ART contouring within a high-volume CTgART clinic. The timing data presented demonstrates an improvement in contouring time when comparing APRT versus physician contours.

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CRediT authorship contribution statement

Robbie Beckert: Conceptualization, Data curation, Writing – original draft. **Joshua P Schiff:** Conceptualization, Writing – review & editing. **Eric Morris:** Formal analysis, Writing – review & editing. **Pamela Samson:** Conceptualization, Writing – review & editing. **Hyun Kim:** Conceptualization, Writing – review & editing. **Eric Laugeman:** Supervision, Conceptualization, Data curation, Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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