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Scientific Article

Early Experience of Online Adaptive Radiation Therapy for Definitive Radiation of Patients With Head and Neck Cancer

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Purpose: The advent of cone beam computed tomography–based online adaptive radiation therapy (oART) has dramatically reduced the barriers of adaptation. We present the first prospective oART experience data in radiation of head and neck cancers (HNC).

Methods and Materials: Patients with HNC receiving definitive standard fractionation (chemo)radiation who underwent at least 1 oART session were enrolled in a prospective registry study. The frequency of adaptations was at the discretion of the treating physician. Physicians were given the option of delivering 1 of 2 plans during adaptation: the original radiation plan transposed onto the cone beam computed tomography with adapted contours (scheduled), and a new adapted plan generated from the updated contours (adapted). A paired *t* test was used to compare the mean doses between scheduled and adapted plans.

Results: Twenty-one patients (15 oropharynx, 4 larynx/hypopharynx, 2 other) underwent 43 adaptation sessions (median, 2). The median ART process time was 23 minutes, median physician time at the console was 27 minutes, and median patient time in the vault was 43.5 minutes. The adapted plan was chosen 93% of the time. The mean volume in each planned target volume (PTV) receiving 100% of the prescription dose for the scheduled versus adapted plan for high-risk PTVs was 87.8% versus 95% ($P < .01$), intermediate-risk PTVs was 87.3% versus 97.9% ($P < .01$), and low-risk PTVs was 94% versus 97.8% ($P < .01$), respectively. The mean hotspot was also lower with adaptation: 108.8% versus 106.4% ($P < .01$). All but 1 organ at risk (11/12) saw a decrease in their dose with the adapted plans, with the mean ipsilateral parotid ($P = .013$), mean larynx ($P < .01$), maximum point spinal cord ($P < .01$), and maximum point brain stem ($P = .035$) reaching statistical significance.

Conclusions: Online ART is feasible for HNC, with significant improvement in target coverage and homogeneity and a modest decrease in doses to several organs at risk.

Introduction

Intensity modulated radiation therapy (IMRT) has become the standard-of-care radiation delivery technique for treatment of head and neck cancers (HNC) due to its established benefit in improving late side effects.[1-3] However, the conformality of IMRT also predisposes the

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treatments to significant delivered dose discrepancies due to changes in the patient (eg, weight loss or muscle atrophy) or tumor (eg, treatment response or tumor edema). Daily cone beam computed tomography (CBCT) can help reduce setup error between treatments, but it cannot adjust for these volume changes.

Adaptive radiation therapy (ART) is the process of replanning patients during their radiation therapy course to account for these patient and tumor changes. ART has traditionally been considered a prohibitively resource-intensive process and only performed once or twice during the course of a conventional HNC radiation therapy in very select patients. However, advances in automation and artificial intelligence have enabled accelerated adaptive planning workflows to be more streamlined and require less human intervention. Recently, a CBCT-based online ART (oART) system, whereby artificial intelligence and deformable image registration automate the contour generation and plan generation, was made available for clinical use. ART can now be performed online while the patient is laying on the treatment table. Online ART is of particular interest in HNC because patient and tumor changes are common in this patient population.[4] These changes can lead to poor target coverage and cold spots in the tumor and increased dose and hot spots in the many sensitive head and neck organs at risk (OARs). There is likely a greater need for adaptation for HNC than can be realistically accomplished using offline ART, given the resource utilization needing to resimulate and replan a patient with HNC using traditional techniques.

The data on the possible advantages of ART in HNC is still limited to small, mostly simulated or offline adaptive studies.[4] Several studies have showed the decrease in the volume of the gross primary and nodal volumes as the treatment progresses, with one study seeing an average of 90% primary and 60% nodal gross tumor volume reduction by week 4.[5,6] Changes in anatomy can also be expected in the OARs. For example, parotid glands are of particular interest in ART because of their radiosensitivity and association with xerostomia.[7,8] Studies have shown that the average volume of the parotids decrease and the parotid glands move superiorly and medially during treatment, with feasibility studies demonstrating mean parotid dose reduction by as much as 5.5 Gy with ART.[9-14] Other OARs, such as spinal cord, mandible, and submandibular glands (SMG), also have the potential to benefit from ART.[9,15-17]

Despite the preliminary data supporting the regular use of ART for HNC treatments, the complexity of HNC radiation planning creates challenges for implementing oART. The true resources utilization, efficacy of software, plan quality, and target/OAR benefit of oART for patients with HNC is not known. We present, to our knowledge, the first prospective experience of treating HNC with oART. We also summarize the lessons learned from the initial experience with this system.

Methods and Materials

Patients with HNC receiving radiation who are planned for at least 1 oART treatment were enrolled on a prospective registry study. Patients undergoing adjuvant or palliative radiation and those whose adaptation volume were considered limited (eg, adaptation of only a boost volume) were excluded from this analysis to keep the study population and radiation plans homogeneous.

The frequency of the adaptations was at the discretion of the treating physician. The same oART platform was used for each patient. Online ART begins with a baseline IMRT plan generated from a CT simulation scan. At the time of ART, CBCT was obtained and checked for quality before being used to generate and edit the influencer OARs. The influencer structures typically consisted of the spinal cord, mandible, and the parotid glands. Influencers are used to guide the deformation algorithm to propagate structures from the planning CT to the CBCT. Once the influencers were approved, the oART software generated new target volumes and the remaining OARs, which the treating physician then reviewed and modified. Next, the oART software generated a new adapted plan. The treating physicians were then given the option of delivering 1 of 2 plans: the original baseline radiation plan transposed onto the CBCT with updated adapted contours (scheduled) or the new adapted plan generated from the updated contours (adapted). Calculation-based quality assurance (QA) was run if the adapted plan was selected. Another CBCT was done to ensure there was no change in position during the adaptation before delivering the chosen plan. The patient remained on the treatment table during the whole oART process. The selected treatment plan, whether scheduled or adapted, continued to be delivered for each fraction until the next oART or completion of radiation. For dose analysis of OARs and PTVs in this paper, though, the scheduled plan was always the original baseline plan developed on the CT simulation scan transposed onto the CBCT with adapted contours to avoid comparing 2 adapted plans. The preplan dose analyses are from the original plan on the CT simulation scan.

Adaptive radiation therapy process time is defined as the time from influencers editing to the QA approval. Physician ART time was defined as the time for physician arrival to QA approval. The time at which the physician was paged to the machine changed at the end of the data gathering. Initially, physicians would be paged right before the CBCT. Near the end of this study period, trained therapists would contour the influencers before paging the treating physician. Patient ART time was defined as the period from when the patient entered the treatment vault to the time the patient left the treatment

vault. A radiation therapist recorded the time data to the nearest whole minute.

The current analysis compares the dosimetric OAR and target data between the scheduled and adapted plans presented to the treating physician. Mean dose to the oral cavity, superior constrictor muscles, middle constrictor muscles, inferior constrictor muscles, parotid glands, SMGs, larynx, and esophagus were assessed. OARs whose mean doses per fraction were either greater than 180 cGy or less than 10 cGy were excluded from analysis because they were either too close or too far from the target to influence the final dose distribution. Max point dose (Dmax) to 0.035 cc was analyzed for the spinal cord, brain stem, and mandible.

The target analysis looked at the volume in each PTV receiving 100% of the prescription dose (V100%) as well as the Dmax in the PTVs. The dosimetric data are analyzed as a per-fraction-dose format because the scheduled and adapted plans were only compared at the time of the ART session. It was not known how the differences between the 2 plans would change with the remainder of the treatments. However, a hypothetical difference was created by multiplying the average dosimetric difference between the 2 plans by 35 to help understand how the dose-per-fractions difference would play out over a whole hypothetical definitive radiation course. A paired *t* test was used to compare the doses between scheduled and adapted plans.

Results

Patient information

A total of 28 patients with HNC planning to undergo oART signed consent to be included on the prospective ART registry study between July 2021 and March 2022. Seven patients were excluded due to palliative treatment (n = 2), adjuvant radiation therapy (n = 2), nonconventional fractionation (n = 2), and lack of any adaptive fractions (n = 1). In the end, a total of 21 patients were included in the current analysis (Table 1). Two patients did not have their ART data saved, so 19 patients were included in dose analysis. All but 1 patient received standard fractionation in 33 or 35 fractions. This patient had extranodal natural killer/T-cell lymphoma nasal type and received 50 Gy in 25 fractions. All patients were treated with concurrent chemotherapy. The majority of patients (15/21, 71%) had an oropharynx primary, 10 of whom (67%) were p16 positive.

Table 1 Patient characteristics

Characteristic	No. (%)
Sex	
Male	19 (90.5)
Female	2 (9.5)
Age, median (range)	65 (45-80)
Concurrent chemotherapy	21 (100)
Primary site	
Oropharynx p16 positive	10 (47.6)
Oropharynx p16 negative	5 (23.8)
Larynx/hypopharynx	4 (19)
Salivary	1 (4.8)
Sinus	1 (4.8)
T stage*,†	
T1	2 (10)
T2	4 (20)
T3	7 (35)
T4	7 (35)
N stage*,†	
N0	1 (5)
N1	9 (45)
N2	7 (35)
N3	3 (15)

* American Joint Committee on Cancer (eighth edition).
† Excluding patient with nasal NK/T cell lymphoma.

Adaptation time information

The patients underwent a total of 43 ART sessions with a median of 2 ART sessions per patient (absolute range, 1-5 ART sessions). The scheduled plan was chosen 3 times (7%). The median fraction at which the first ART was performed was fraction 13.5 (range, 2-29). The median fraction at which ART was performed was fraction 19 (range, 2-32). The mean physician ART time at the console was 30 minutes (median, 27; range, 12-81). The mean ART process time was 26.1 minutes (median, 23; range, 16-50). The mean patient time in the vault was 45.8 minutes (median, 43.5; range, 30-96). There was no statistically significant change over time in any of these time measurements, although all 3 had a negative trend (Fig. E1). Times for different ART steps are displayed in Fig. 1.

Target coverage information

Target coverage saw consistent improvement with the adapted plans (Table 2). The mean V100% for high-risk PTVs improved from 87.8% in the scheduled plan to 95% in the adapted plan (n = 38; $P < .01$). Improvement was also noted in the mean V100% for intermediate-risk PTVs, going from 87.3% to 97.9% (n = 34; $P < .01$), and for the low-risk PTVs, going from 94% to 97.8% (n = 35; $P < .01$). Only 15.8%, 35.3%, and 60% of the scheduled plans met the typical V100% ≥ 95% criteria for the high-

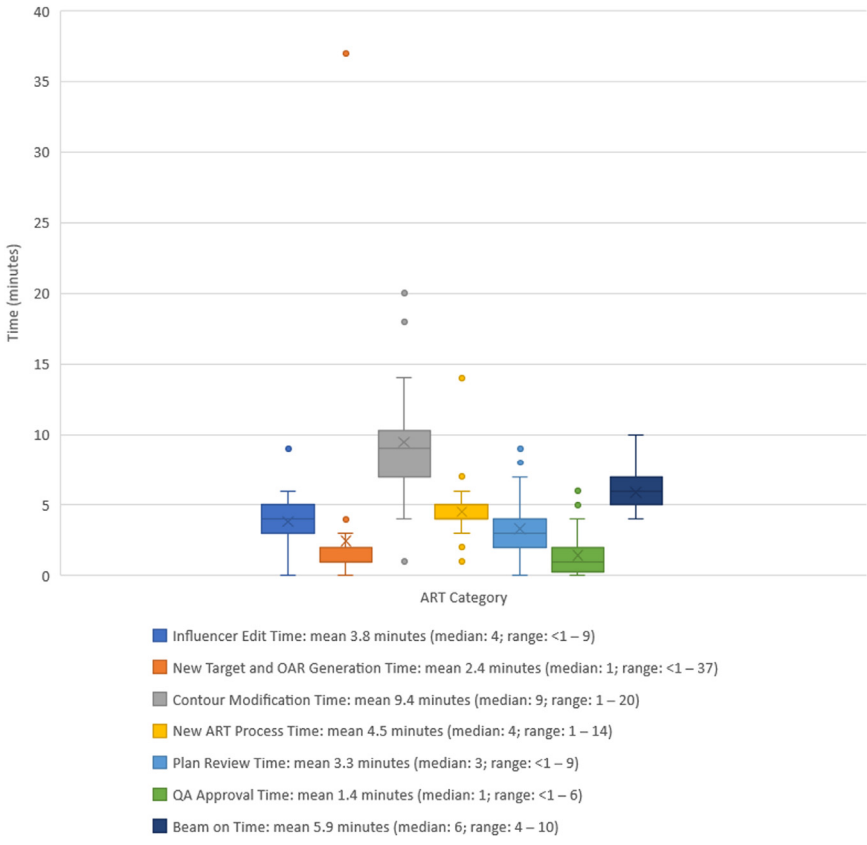

Figure 1 Adaptation time results. Box-and-whisker plot denotes the minimum (excluding outliers), first quartile, median, third quartile, and maximum (excluding outliers) values. X denotes mean values. Dots denote outlier values (outside the 1.5 × interquartile range from the quartiles). *Abbreviations:* ART = adaptive radiation therapy; OAR = organ at risk; QA = Quality Assurance.

risk PTV, intermediate-risk PTV, and low-risk PTV, respectively. In the adapted plan, 94.7%, 94.1%, and 94.3% met the typical V100% ≥ 95% criteria for the high-risk PTV, intermediate-risk PTV, and low-risk PTV, respectively. In the original plans, the V100% ≥ 95% coverage was met 89.5%, 100%, and 100% of the time for the high-risk PTV, intermediate-risk PTV, and low-risk PTV respectively. Two patients did not meet their high-risk V100% on the original plans due to having bulky disease near critical OARs. The mean Dmax was statistically lower in the adapted plans versus scheduled plans: 106.4% versus 108.8%, respectively (n = 38; $P < .01$). At our institution, the Dmax goal is typically ≤107%. The Dmax criteria of ≤107% was met in 21.1% of the scheduled plans and 71.1% of adapted plans compared with 94.7% of the original plans.

OAR information

The OARs saw more variable changes between the scheduled and adapted plan (Table 3). The difference in the number of each OAR structure analyzed is due to exclusion of structures from the preplan OAR dose

Table 2 Comparison of target coverage and maximum point

Target Parameter	Preplan (%)	Scheduled (%)	Adapted (%)
Mean low-risk PTV V100% (range)	98.1 (95.3–99.3)	94 (63.9–99.2)	97.8* (92.1–99.7)
Mean intermediate-risk PTV V100% (range)	97.4 (92.7–99.9)	87.3 (33.3–99.3)	97.9* (93.8–100)
Mean high-risk PTV V100% (range)	95.3 (93.1–97.2)	87.8 (25.4–97.4)	95* (89–97.3)
Mean maximum point	106.1 (104.4–109.9)	108.8 (104.5–118.5)	106.4* (104.4–110.4)

Abbreviation: PTV = planned target volume; V100% = the volume in each PTV receiving 100% of the prescription dose.
* Statistically significant difference ($P < .01$) from the scheduled plan.

Table 3 Comparison of OAR dose between the scheduled and adapted plans

OAR	Number	Scheduled plan (cGy)	Adapted plan (cGy)	Difference over a treatment course* (Gy)	Mean % difference	Minimum relative difference (%)	Maximum relative difference (%)	*P* value
Oral cavity mean	36	60.4	58.5	−0.67	−3.2	−34.21	73.91	.39
Superior constrictor mean	11	87	86.7	−0.11	−0.31	−57.89	24.78	.94
Middle constrictor mean	22	94.9	93.3	−0.56	−1.7	−37.87	37.04	.6
Inferior constrictor mean	21	60.5	60.5	0	−0.03	−17.58	19.84	.99
Parotid ipsilateral mean	28	74.9	65.5	−3.29	−12.53	−43.53	40.54	**.013**
Parotid contralateral mean	36	46.8	48.9	0.74	4.57	−25	75.38	.08
SMG contralateral mean	25	79.3	74.7	−1.61	−5.83	−60.27	29.11	.16
Larynx mean	26	86.3	77.5	−3.08	−10.17	−28.32	18.57	**<.01**
Esophagus mean	35	59	57.6	−0.49	−2.3	−17.39	54.24	.38
Spinal cord Dmax	38	111.3	101.7	−3.36	−8.63	−28.68	24.62	**<.01**
Mandible Dmax	36	202.6	200.8	−0.63	−0.88	−6.88	15.66	.09
Brain stem Dmax	19	101.8	94.5	−2.56	−7.24	−26.15	17.78	**.035**

Abbreviations: Dmax = maximum dose; OAR = organ at risk; SMG = submandibular gland.

* Theoretical benefit if the difference between the scheduled and adapted plan is multiplied over a definitive course of 35 fractions. Hypothetical analysis performed for easier understanding of the dose-per-fraction difference between the 2 plans.

Values in boldface are statistically significant.

constraints (being too far from or being part of PTVs) or due to the prespecified dose exclusion outlined in the Methods and Materials section. Eleven of 12 measured OARs saw numerical decreases in mean dose with oART. Only the mean larynx dose, mean ipsilateral parotid dose, brain stem Dmax dose, and spinal cord Dmax dose saw statistical improvement with the ART plans. The contralateral parotid saw a nonsignificant increase in dose per fraction with oART. The mean percent differences were small between the scheduled and adapted plans, with the largest improvement with oART seen with the ipsilateral parotid, for which the average reduction in dose with the ART plans was 12.5%. The largest absolute mean hypothetical difference through a whole definitive treatment course was −3.36 Gy seen in the spinal cord Dmax. Therefore, even if the single adaptation was hypothetically propagated for 35 fractions, the absolute improvements in the OAR dosimetry were modest. However, there was a large range in the relative differences between the scheduled and adapted plan from adaptation to adaption, with the difference ranging from −61.5% to +73.9%.

Similar OAR analyses were performed on the subgroups of patients who had node positive disease (n = 17) and on patients who had T3/4 disease (n = 13). In the analysis of node positive patients, there was now a statistically significant decrease in the esophagus dose from 59.1 cGy to 56 cGy per fraction ($P < .01$), but the brain stem Dmax decrease was no longer significant (Table 4). In the analysis of T3/4 disease, there was a significant decrease in the mandible Dmax from 204.3 cGy to 201.5 cGy ($P < .01$) and in the mean contralateral SMG from 70.2 cGy to 60.3 cGy ($P < .02$) with ART (Table 4). However, the brain stem Dmax and the ipsilateral parotid mean dose decrease were no longer statistically significant.

Discussion

To our knowledge, this analysis is the first published report on the clinical experience of online CBCT-based ART for HNC treatment, showing that oART is feasible within a reasonable period for patients and physicians. OART plans showed statistically improved coverage and decreased hot spots compared with scheduled plans, but the benefits to OARs were less consistent. Nevertheless, mean larynx dose, mean ipsilateral parotid dose, brain stem Dmax dose, and spinal cord Dmax dose showed statistical improvement over the scheduled plans.

The patient oART time was well tolerated, but there is still room for optimization. For example, Yoon et al[18] were able to achieve a median ART plan generation time of 19.5 minutes in a retrospective simulated environment. These were the first patients with HNC treated with oART in the department, which came with the expected learning curve. The ART times were affected by learning how to efficiently adapt contours, evaluate plans, troubleshoot errors, and optimize workflow. Some of these lessons are summarized later in the Discussion section. In fact, the 3 times that the scheduled plan was chosen was due to uncertainty in the accuracy of the adapted plan,

Table 4 Comparison of OAR dose between the scheduled and adapted plans for node-positive patients and patients with T3/4 disease

OAR	Number	Scheduled plan (cGy)	Adapted plan (cGy)	Mean % difference	*P* value
Node-positive patients					
Oral cavity mean	34	60.2	57.1	−5.26	.14
Superior constrictor mean	8	104.6	104.4	−0.26	.96
Middle constrictor mean	21	94.5	92.8	−1.8	.6
Inferior constrictor mean	21	60.5	60.5	−0.03	.99
Parotid ipsilateral mean	26	75.8	66	−13.02	**.02**
Parotid contralateral mean	34	46.6	48.4	3.78	.15
SMG contralateral mean	22	79.2	79	−0.33	.91
Larynx mean	25	87.6	78.8	−10.1	**<.01**
Esophagus mean	32	59.1	56	−5.28	**<.01**
Spinal cord Dmax	34	112.3	101.4	−9.65	**<.01**
Mandible Dmax	34	202	200.3	−0.85	.12
Brain stem Dmax	18	99.7	93.3	−6.41	.07
Patients with T3/4 disease					
Oral cavity mean	27	64.4	62.1	−3.68	.41
Superior constrictor mean	6	99.3	92.8	−6.54	.31
Middle constrictor mean	15	98.1	99.3	1.19	.52
Inferior constrictor mean	14	66.9	65.6	−1.85	.55
Parotid ipsilateral mean	22	77.4	68.7	−11.24	.052
Parotid contralateral mean	27	48.7	49.5	1.68	.48
SMG contralateral mean	16	70.2	60.3	−14.2	**.02**
Larynx mean	19	87.4	79.3	−9.33	**<.01**
Esophagus mean	27	66.2	64	−3.2	.3
Spinal cord Dmax	29	112.2	101.8	−9.32	**<.01**
Mandible Dmax	27	204.3	201.5	−1.37	**<.01**
Brain stem Dmax	13	103.2	97.2	−5.83	.22

Abbreviations: Dmax = maximum dose; OAR = organ at risk; SMG = submandibular gland.
Values in boldface are statistically significant.

mostly stemming from inaccurate body contour generated by the oART system. We also initially favored enrolling patients with more advanced disease under the presumption that they are most likely to benefit from oART. These more advanced cases also contributed to making oART more challenging and time consuming. For example, 1 patient with HNC also needed new 3-dimensionally-printed boluses, which were prefabricated from previous CBCTs, for each adaptation session to cover their shrinking exophytic skin disease before the ART session. Although no pattern could be elicited from the time data, the negative trends in physician, patient, and ART process time (Fig. E1) likely reflect an early improvement in efficiency.

The most salient benefit from our early oART data appears to be improving PTV coverage and homogeneity. The adaptive plan optimizer was set to prioritize PTV coverage and homogeneity, likely explaining this finding. The advanced presentations treated in this early cohort likely further enhanced these findings because the large primary and nodal disease can have substantial anatomic change as it responds to treatment. These results are in line with the benefit seen in PTV coverage in offline ART studies.[15-17,19-21] Perhaps the most surprising result is the percentage of scheduled plans that did not meet the prespecified V100% and Dmax planning criteria. To verify whether the improved coverage with ART will result in improved disease outcomes will likely require a sizable prospective HNC study. Retrospective data does suggest that there may be disease outcomes benefit to adaptation.[22,23] However, given the successful track record of non-ART IMRT in HNC with most recurrences

developing in-field, it may be more appropriate to prioritize critical OAR doses over coverage in some cases to improve the short- and long-term side-effect profile.

The mean dose to each OAR was numerically lower with adapted plans except the contralateral parotid gland. The contralateral parotid was a high-priority OAR that received the lowest dose per fraction among OARs, so there was likely not much room for improvement with adaptation. The minimum and maximum relative differences in Table 3 also highlight the relative spectrum of results we see with the adaptive treatment plans. In the subgroup analysis of patients with T3/4 disease, statistical benefits were seen in the maximum dose to the mandible and the mean contralateral SMG dose, improvements which may translate to improved long-term quality of life. These results can be attributed to the fact that these structures are the closest OARs to the large primary tumors, which can be better avoided during ART if the primary tumor begins to shrink. These subgroup analyses, along with the wide-ranging minimum and maximum relative difference, demonstrate that patient selection is important in assessing the efficacy of oART. Especially given the combination of the time investment at the machine and generally unimpressive OAR improvements, our results further support efforts to answer patient-specific adaptation questions, such as who benefits the most from ART, how often should ART be performed, and when should ART be performed.[21,24-26]

The CBCT-guided oART system features automations in the ART process and uses the optimization goals and priorities set up in the preplan to optimize the new online adapted plan. There is no chance to make any modifications to these goals and priorities during the ART sessions. This helps lead to a more robust ART process. However, the chance to spare OARs more aggressively by adjusting to more strict OAR constraints when the tumor shrinks away from the OARs is missed. Offline studies with manual planning can more readily take advantage of this change compared with the current online study with autoplanning.[15-17,19-21] Online ART also has to be performed with the patient's time on the treatment table in mind. Along with not having a contrast-enhanced CT simulation scans to do contours, the time limitations are not conducive to more nuanced volume de-escalation. These practical considerations may explain why some simulated or offline environments have reported more consistent OAR dose benefits with ART.[5,13,16,18,20]

Lessons learned

The automation in the oART software offers an efficient workflow but also creates some "black-box steps" that need careful consideration and troubleshooting. The accuracy of the body contour is one such issue that needs consistent attention. The body contour was automatically detected by the software, and the synthetic CT was subsequently generated for dose calculation. The software does not allow for body contour modification during the process, which may be problematic because incorrect body contours compromise both the accuracy of PTV cropping from skin and, more generally, the accuracy of dose calculations (Fig. 2). The most consistently inaccurate area was the neck contour under the chin. The body contour for patients with HNC is prone to error because the aquaplast mask may be falsely recognized as the skin and from rapid changes over time from disease shrinking and/or weight loss.

There are several techniques we employed to help minimize body contour inaccuracies. First, we optimized

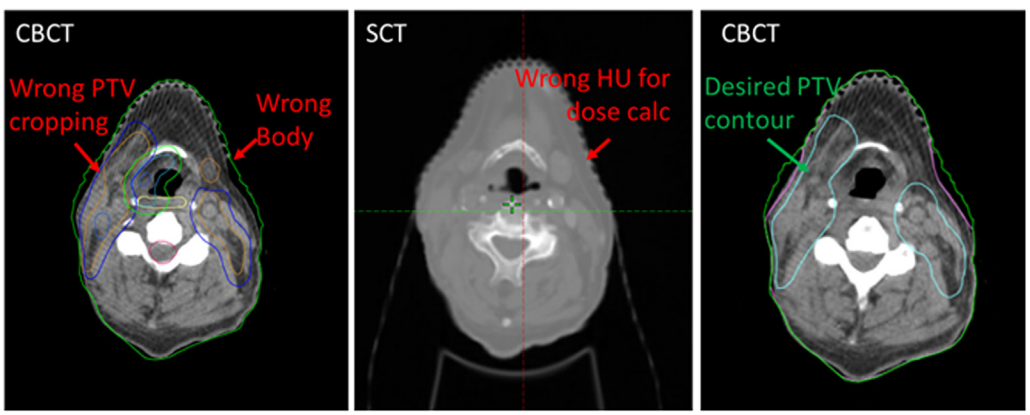

Figure 2 Example of inaccurate body contour resulting in incorrect planned target volume (PTV) and density/Hounsfield unit (HU) for dose calculation. The first image shows an incorrect body contour (green) going into air and the improper cropping of the PTV (blue) from the skin due to this body contour error. The second image shows that the portions of the incorrect body contour are also filled in with an incorrect HU (red arrow), thus making the dose calculations slightly inaccurate. The third image shows the desired body contour (pink) and the preferred PTV cropping from the skin (light blue). *Abbreviations:* CBCT = cone beam computed tomography; SCT = synthetic computed tomography.

CBCT scanning protocol to achieve the optimal CBCT quality. In our experience, slow thoracic scans with iterative CBCT appeared to be less prone to these errors. Second, cutting out the aquaplast mask in the neck under the chin helped increase the accuracy of the body contour under the chin without increasing setup error. Third, when a bite block was used, we 3-dimensionally printed a piece of 3-mm bolus to place at the end of the bite block to simulate a pair of closed lips when acquiring the planning CBCT. Our bite block had a density closer to air; as a result, the body contour would be pushed into the oral cavity without the bolus.

Other techniques were also implemented to help decrease the oART time commitment. First, as the comfort with oART increased, adapting PTVs, rather than clinical target volumes or gross tumor volumes, was felt to be the quickest way to generate adapted contours without having to worry about the accuracy of postcontouring autoexpansions. This was particularly helpful when inaccurate body contours caused concern about improper clinical target volume or PTV clipping. In addition, when the software clips a large volume of OARs/PTVs going outside the body contour, it was prone to causing the software to crash. Training therapists to contour influencers was also an effective way to decrease physician time at the machine. The influencers were typically deformed accurately onto the CBCTs and were easy to contour if there were any issues. Therapist contouring also saved the physicians from having to wait at the machine for the generation of a new target and OARs after the influencers were edited.

A robust optimization approach is crucial to ensure the adequate plan quality of the real-time reoptimized plans because the system does not allow any modification of optimization goals or priorities during oART. In our experience, peer review of the planning approach between the physicists and the planners before the physician's review of the initial scheduled plan is effective in detecting deficiencies of plan setup and optimization approach. Common deficiencies include conflicting goals and overly complicated tuning structures that may be counterproductive when the anatomy changes. A dedicated checklist was developed for treatment peer review to standardize the process.

Conclusion

The current clinical prospective experience of oART in head and neck definitive chemoradiation has shown the feasibility and potential benefit of oART for this patient population. Online ART plans showed statistical benefit over scheduled plans in PTV coverage, PTV dose homogeneity, and doses to certain OARs. Further studies and experience are needed to improve and quantify the benefit of oART. Ultimately, it is critical to show that any dosimetric improvement with ART translates to a meaningful clinical advantage by assessing toxicity and quality-of-life data. Studies at our institution and others are underway.[27,28]

Disclosures

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.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.adro.2023.101256.

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