Deformable CBCT for Daily Adaptive Radiotherapy in Head and Neck Cancer Patients: A More Reliable and Practical Approach for Improved Precision

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ABSTRACT

Introduction: Practical application of adaptive radiotherapy (ART) in head and neck cancer (HNC) has not been formalized despite the availability of cone beam computed tomography (CBCT). This study compares the use of deformable CBCT to other clinical methods to identify patients that need ART.
Methods: A comparison was made between daily CBCT data to the use of weight ≥ 5% and a source to skin distance (SSD) ≥1cm as markers to prompt ART. The planning CTs (pCT) were deformed onto the CBCT along with the high risk PTV and OARs. The process is then reversed and the newly deformed CBCT is imported into Eclipse where the plan is recalculated to maintain the pCT Hounsfield units. The sensitivity of CBCT versus clinical parameters in identifying events were analyzed for the need of ART.
Results: Dose deviation occurred in parotid glands (58%) and spinal cord (33%). The utilization of CBCT along with a deformation software provided 100% sensitivity to identify patients benefiting from replanning, and weight loss >5% and SSD >1cm were associated with 50% and 33% sensitivity, respectively.
Conclusion: Compared to clinical parameters, deformable CBCT was demonstrated to be the most reliable method for tracking patients requiring ART and, significantly, protecting the organs at risk (OARs).

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INTRODUCTION

Adaptive radiotherapy (ART) is used in head and neck cancer (HNC) patients to account for volumetric and dosimetric changes during the 7-week treatment. Practical application of ART has not been formalized despite the availability of cone beam computed tomography (CBCT). This study compares the use of deformable CBCT to other clinical methods to identify patients that need replanning while reducing workload.

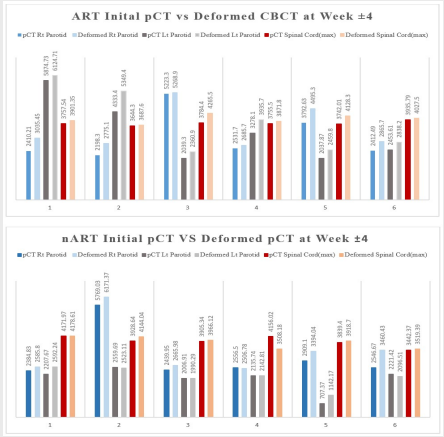

Figure 1 &2 . Doses to OARs and Target Volumes

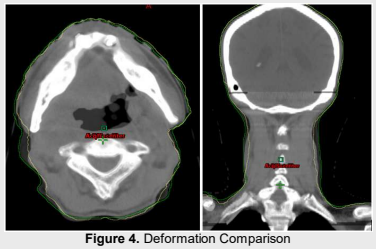

Figure 4. Deformation Comparison

METHODS AND MATERIALS

Two cohorts, each consisting of six HNC patients, underwent definitive treatment with VMAT. The first cohort was marked as ART for those who were replanned and the second cohort was marked as nART for those who were not replanned. All twelve patients, before their planning computed tomography (pCT) scan, a custom thermoplastic head and shoulder mask was made. For daily positioning of the patient, the radiation therapist aligns the patient and a CBCT is taken before each treatment delivery to confirm patient positioning. Adjustments of the CBCT are made by the radiation therapist (RT) to align to the pCT. If the RT found that the patient's CBCT was not in alignment with the pCT then the radiation oncologist would analyze the comparison. Decisions regarding the need for ART were based on the discrepancy between the CBCT alignment, percentage of weight loss, and the SSD to the thermoplastic mask.
For the ART patients, a selection of CBCT were archived from the day prior to the replan. These CBCTs were mostly at week 4 (±4). For the nART patients, CBCT showing a notable change in anatomy and target structures at week ±4, were imported into Varian Velocity. In Velocity the pCTs were deformed onto the CBCT along with the high risk PTV and OARs. This process is then reversed so that the CBCT is deformed onto the pCT to maintain the original pCT Hounsfield unit as well as to maintain the full body image of the original pCT. The new deformed structures and plan are imported into Eclipse and the plan is recalculated with preset monitor units. The data collection included parameters such as weight loss ≥5%, separation ≥1cm in SSD, and dose deviation criteria, such as parotid mean dose >26Gy, spinal cord maximum dose >40Gy, brainstem maximum dose >54Gy, mandible maximum dose >105%, and a mean difference ≥5% for PTV, all of which were considered events requiring ART.

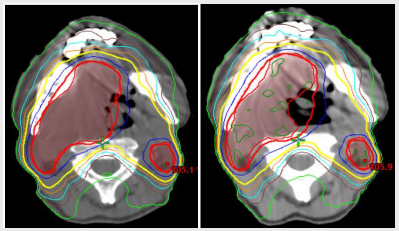

Figure 3. pCT and deformed CBCT

RESULTS

Variations of more than 5% weight loss, more than 1cm SSD, and dose deviations on OARs are significantly higher in the ART group as seen in Table 1. The change in SSD of >1cm was observed in four ART patients and in two nART patients. The sensitivity of SDD as a trigger factor for the ART group was 50% versus 17% for the nART group. However, one patient from the ART group would have not been identified by using SSD alone to determine ART. Using the CBCT, it was determined that one patient that did not exceed the SSD tolerance, would have benefited from being replanned. To the contrary, a patient from the ART group that had met the more than 1cm tolerance, did not need to be replanned. Due to the deformed CBCT, the tolerances for this patient did not exceed any OARs and had minimal decrease in the mean PTV of 0.49%. This patient did not need to be replanned but it was preformed because of the anatomical difference of the daily CBCT and pCT along with the SSD separation of more than 1cm being used as a trigger factor for this patient. Moreover, in the nART group, two patients exceeded the SSD of more than 1cm, but were not replanned due to meeting the acceptable dose constraints on the daily CBCT compared with the pCT. Deformation of the CBCT showed that all OARs were in tolerance and the mean PTV coverage had an insignificant increase of 0.79% for one patient. Whereas, for the other patient, the deformed CBCT showed that there was a need for ART because the tolerance for one of the parotids was exceeding the acceptable level.
The weight loss of more than 5% from the initial weight happened in 80% and 83% in ART and nART patients, respectively. The sensitivity of weight loss was 67% in the ART group verses 33% in the nART group. In the ART group, the weight loss of more than 5% missed one patient that would have benefited from ART due to a parotid exceeding the tolerance as seen in Figure 1. Five patients from the nART group that had weight loss of more than 5% did not receive adaptive radiotherapy. The sixth patient maintained the weight and was not replanned due to minimal anatomy changes. As seen in Figure 2, the deformed CBCT shows that there was no reason to replan this patient due to all OARs being in tolerance. From the five patients in the nART group, it was determined that no replanning was needed because the daily CBCT and pCT had minimal changes. Interestingly enough, the deformed CBCT showed that three of the patients who did not receive ART had a decreased mean dose to the contralateral parotid. The dose to the spinal cord for these patients did increase, but it was still well below tolerance due to our clinic having a planning objective of maximum dose of 40Gy. The other two patients from the five patients that had more than 5% weight loss were missed from having replans due to the minimal changes at the time of the daily CBCT and the pCT comparison. The deformed CBCT showed that there was an increase in dose to one of the parotids, thus exceeding the tolerance. The spinal cord and contralateral parotid for these two patients were well under tolerance.

Indications	ART	nART
Mean Initial Weight	208.97lbs (174.2 - 231.5)	203.35lbs (84.5 - 228.9)
Mean Weight at Week ±4	191.17lbs (151.6 - 332.9)	192.35 (84.7 - 313.1)
Mean % Weight Change	8.43% (0.59 - 13.52)	4.8% (0.25 - 6.16)
Mean initial SSD	185.2cm (180.6 - 186.9)	186.88 (183.5 - 190.1)
Mean SSD at Week ±4	187.02cm (185.4 - 189.7)	187.28cm (184.2 - 190.4)
Mean SSD Change	1.82cm (-1 - 2.8)	0.4cm (-0.7 - 1.9)
Mean initial PTV Mean Coverage	7165.77cGy (7116.9 - 7194.7)	7148.5cGy (7086.9 - 7203.9)
Mean PTV Mean Coverage at Week ±4	7241.95 (7082.2 - 7369.8)	7164.53cGy (7065.3 - 7243.1)
Mean PTV Mean % Coverage Difference	1.06% (-0.49 - 2.16)	0.22% (-0.45 - 0.79)
Mean Right Parotid Mean Dose	3094.77cGy (5223.3 - 2198.3)	3101.01cGy (2384.82 - 5769.03)
Mean Right Parotid Mean Dose Change	426.25cGy (45.6 - 702.67)	363.05cGy (-49.72 - 913.76)
Mean Left Parotid Mean Dose	3336.17cGy (5874.73 - 2039.9)	1973.13cGy (707.37 - 2559.69)
Mean Left Parotid Mean Dose Change	508.62cGy (1016 - 249.98)	108.06 (-124.91 - 434.8)
Mean Spinal Cord Max Dose	3769.92cGy (3644.3 - 3757.54)	3907.29 (4171.97 - 3839.4)
Mean Spinal Cord Max Dose change	210.42cGy (43.3 - 389.29)	-34.78 (-647.84 - 215.4)
Mean Mandible Max Dose	103.35% (101.15 - 105.37)	102.86% (100.51 - 105.46)
Mean Mandible Max Dose Change	2.39% (0.40 - 3.56)	1.03% (-1.32 - 5.38)
Mean Brainstem Max Dose	4643.54 (4157.79 - 5113.63)	3899.12 (2979.19 - 5152.3)
Mean Brainstem Max Dose Change	80.91cGy (-33.8 - 345.38)	-3.50 (-103.9 - 53.09)

Table 1. Mean Doses

CONCLUSIONS

This study compares the use of SSD separation, weight loss, and CBCT with Varian Velocity DR to determine the need for adaptive radiotherapy planning in clinical practice. Our study found that a combination of weight loss and SDD, along with the comparison of daily CBCT scans with the pCT, had a median performance in predicting the benefit of ART. The method was equally effective in identifying patients who would benefit from ART and those who would not. To our knowledge, this is the first study to show the issues and benefits with utilizing CBCT and a deformable software to trigger ART. CBCT was shown to provide the most reliable method in tracking patients in need of ART compared with clinical parameters and, more importantly, it provides an accurate way to minimize the dosimetrist workload.