Automated Dose Accumulation for Online Adaptive Radiotherapy of Head and Neck cancers

S. GROS [1], A. SANTHANAM[2], D. ELLIOTT [3], J. ROESKE [1], R. PATEL[1] and H. KANG[1]
1 Loyola University Chicago, Stritch School of Medicine, Maywood, IL
2 University of California, Los Angeles, CA
3 SegAna Inc, Orlando, FL

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INTRODUCTION

Head and Neck Cancer (HNC) patients often experience progressive anatomical changes during Radiation Therapy (RT). Negative dosimetric impacts from weight loss, tumor and organs at risk (OARs) regression may lead to cancer recurrence or radiation toxicity [1].

Adaptive Radiation Therapy (ART) detects and compensates for these changes by re-optimizing treatment plans to account for the most current patient anatomy. However, the implementation of ART by most clinics is challenging due to lack of resources and technical limitations [2].

AIM

RTapp™ (SegAna, Orlando, FL), a new ART platform, was tested with HNC patient data. RTapp™ allows the automatic visualization of daily anatomical changes throughout an entire course of RT treatment and predicts when treatment plans will exceed pre-defined dosimetric endpoints [3].

METHOD

RT treatment data from 10 HNC patients were retrospectively processed with RTapp™. Each patient study consisted of the planning CT, RT structures, RT Dose, and included all daily sets of CBCT alignment images.

The initial plan CT and structures were deformed to the daily CBCT for each fraction. Adjustments to the deformable image registration (DIR) algorithm were made following assessment of the structure's deformation. The inverse transformation was applied to the plan dose and the daily fraction dose was estimated for each deformed structures.

RTapp™ automatically summed daily fraction doses to calculate the cumulative dose received by each structure after each treatment fractions.

To determine if any patient would have benefitted from adaptive re-planning:

1. The final cumulated dose provided by RTapp™ was compared against the treatment plan dose to estimate whether any dose constraints were violated.
2. The daily dose trend from each structure was evaluated to estimate if their specific planning dose constraints was violated during treatment.

RESULTS

RTapp™ identified anatomical changes on a fraction basis for each patients.

Fig. 1 shows an example visualization of initial structures and dose from treatment planning along with their deformed counterparts for Study 6. Deformed structures (dashed lines) are overlaid on the last daily CBCT. Patients morphological changes, volumes shrinkage and displacement of structures due to weight loss were accurately tracked by the deformable registration algorithm employed by RTapp™.

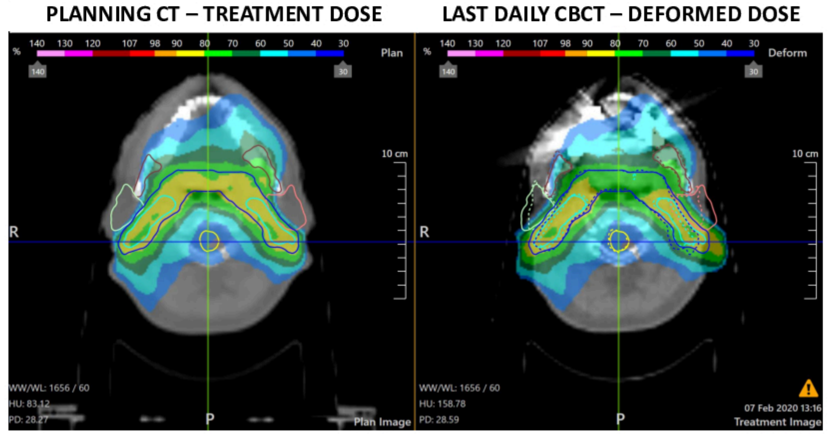


Figure 1. Initial plan CT, structures and dose (left), with corresponding deformed structures and dose overlaid on last daily CBCT (right) for Study 6. Deformed structures are showed in dashed lines.

Seven out of 10 patient studies were flagged for violating their initial planning dose constraints. **Table 1** summarizes the data for the flagged studies.

Most dose constraints violations occurred mid treatment, between fractions 13 (26Gy) and 22 (44Gy). After review of individual 3D-3D daily set-up alignments, the deviation from planned dose constraints was explained by gradual weight loss occurring throughout treatment for all flagged cases.

Patient	Treatment dose (SIB)	Fractions	Structure violating constraint	Dosimetric End point	Treatment plan dose	RTapp final dose	Flagged fraction
1	54Gy/60Gy	30	PTV 60Gy	V[95%] > 95%	95.6%	89.2%	13
2	54Gy/60Gy	30	Rt Parotid	Dmean< 20Gy	19.6	21.1	18
3	56Gy/60Gy/70Gy	35	Lt Parotid	Dmean< 20Gy	19.7	24.4	1
4	54Gy/60Gy	30	Lt Parotid	Dmean< 20Gy	19.6	21.0	22
5	56Gy/60Gy/70Gy	35	Lt Parotid	Dmean< 20Gy	20.0	20.3	1
6	56Gy/60Gy/70Gy	35	Lt Parotid	Dmean< 20Gy	19.5	28.0	1
7	56Gy/60Gy/70Gy	35	Rt Parotid	Dmean< 20Gy	19.1	20.7	33

Table 1: summarized data for flagged studies. All RT treatments were delivered as Simultaneous Integrated Boost with 2 or 3 dose levels over 30-35 fractions.

The first flagged study (1) showed a continuous decrease in PTV coverage. Starting at V95% = 98%, the PTV minimum dose constraints (V95%>95%) was reached mid treatment (fraction 13) with a final coverage value of V95% = 85%.

Fig. 2.A shows the evolution of the PTV 60Gy dose coverage for this study. The dose trend indicates a volume coverage decrease < 95% after 26Gy (fraction 13). The jagged behavior observed after fraction 16 is indicative of daily variations in patient set-up within the immobilization mask due to progressive weight loss.

The DVH obtained from summing the daily fraction doses is shown in **Fig. 2.B** by the dotted line, against the initial plan DVH (straight line).

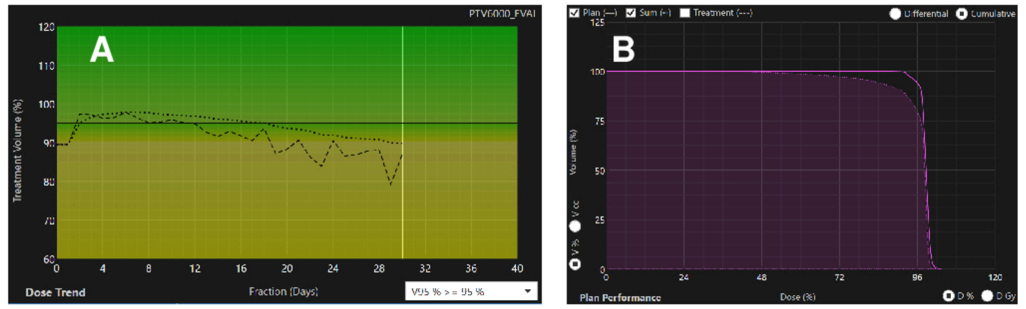


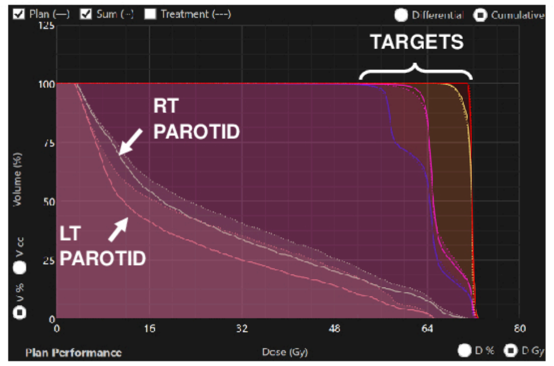
Figure 2. (A) Daily dose trend for PTV 60Gy showing V95% < 95% coverage loss at fraction 13. (B) DVH for PTV60 Gy from initial plan (straight line) and final sum dose based on daily deformations (dotted line).

Most structures exceeding their dosimetric endpoint were Parotids. Studies 3 & 6 flagged on the first fraction have the largest differences between the planned mean parotid dose and the mean parotid dose obtained after deformation. As indicated in Table 1, most plan values were within 1Gy from the 20 Gy limit.

Fig. 3 shows the DVH for PTV targets, Left (light red) and Right (green) Parotids from Study 6. The cumulative dose based on daily deformation (dotted lines) shows no major loss of coverage for all PTVs compared to the initial treatment planning DVH (plain lines). However, both Parotids DVHs display a large dose increase, consistent with the +8.5 Gy mean dose difference recorded in table 1 for the left (spared) Parotid.

Figure 3.

Targets and Parotids DVH showing cumulative doses (dotted line) and treatment plan doses (plain line), from Study 6. The difference between the straight and dotted lines for Parotids of reflect the larger dose received by these OARs with respect to the original treatment plan.



CONCLUSIONS

The RTapp™ software platform provided efficient tools to visualize and estimate the effects of anatomical changes on HNC targets and OARS. Evidence of negative dosimetric impact on PTVs and OARs due to progressive anatomic changes were easily accessible from the dose trend graphs (Fig. 2.A) and by comparing the cumulative deformed dose DVH to the initial plan dose DVH (Figs. 2.B and 3).

The retrospective analysis of 10 HNC patients with RTapp™ revealed that 7 of these patients would have benefited from ART.

In a clinical setting, RTapp™ would be a powerful decision-making tool to predict whether and when specific patients would require adaptive re-planning on a daily basis.

The workflow proposed by RTapp™ will lead to a more efficient use of clinical resources and promote the implementation of ART by small clinics.

This new ART platform could be employed with any body sites where the dose coverage of superficial tumors, nodal targets and organs at risk would be affected by interfraction changes in patient anatomy, such as Gynecologic, Genito-Urinary and Lung cancer sites.

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CONTACT INFORMATION

segros@lumc.edu