Development of Planning Template for Online Adaptive Radiotherapy for Ultra-Central Lung Hypo-Fractionated Treatment

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ABSTRACT

Purpose: We aim to develop and evaluate a template for Ethos v1.1 online adaptive planning using the intelligent optimization engine (IOE) for hypo-fractionated ultra-central lung IMRT (60Gy in 8 fractions). The template includes a dose-boosting planning volume to help deliver a higher dose to the Internal Target Volume (ITV) and to control the location of hot spots. Here, we compare dosimetric results for planning with and without this auxiliary volume.

Methods: The ITV_120 planning structure, i.e., the part of the ITV receiving 120% of the prescription dose, was created by cropping out adjacent OARs, including the proximal bronchial tree, trachea, esophagus, great vessels, spinal cord, and brachial plexus, with a 2-mm margin. Template-generated plans, with and without the ITV_120 structure included in the optimization process, were compared using standard dose metrics.

Results: With the ITV_120 optimization structure in place, the adaptive plan delivered ITV D98% of 7.78±0.38 Gy (7 fractions), which is 3.7% higher than the prescription dose of 7.5 Gy/fx, whereas without it, it was 7.23 Gy (1 fraction). In addition, D99% of the PTV_eval (PTV excluding OARs) for the adaptive plan without the ITV_120 in the template was 6.57 Gy, and with the ITV_120 present it was 6.53±0.15 Gy on average. The dose to the adjacent OARs: proximal bronchial tree and great vessels of the heart was 7.32 Gy and 6.77 Gy, respectively, for the template without the ITV_120, and 7.16±0.13 Gy and 6.70±0.10 Gy, respectively, for the template with the ITV_120.

Conclusions: Our preliminary results show that incorporating the optimization structure ITV_120 into the 8fx Lung hypo-fractionated adaptive treatment template achieved intentional dose escalation to the ITV, focused hotspots in areas free of the adjacent OAR, and facilitated meeting the OAR tolerances.

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INTRODUCTION

The treatment of early-stage ultra-central lung tumors with radiotherapy presents significant challenges due to their location adjacent to multiple critical structures, including the proximal bronchial tree, trachea, esophagus, great vessels, spinal cord, and brachial plexus[1]. Online adaptive radiotherapy provides the flexibility to adjust treatment plans according to daily anatomical variations, enabling improved conformity of high-dose radiation to the tumor volume while minimizing dose to nearby critical structures[2].

The purpose of this study is to develop and evaluate an Ethos v1.1 online adaptive radiotherapy planning template for the treatment of ultra-central lung tumors using hypo-fractionated 9-field IMRT with a prescription dose of 60 Gy delivered in 8 fractions.

Ethos 1.1 Intelligent Optimization Engine (IOE) has ability to generate highly conformal, homogeneous dose distributions across the planning target volume (PTV). For the hypo-fractionated treatments, a greater dose heterogeneity within the target would be beneficial. An appropriately designed planning template incorporating dose-escalation structures can facilitate selective dose boosting within the ITV. This approach enables control over the location of the dose enhancement, helping to maintain doses to adjacent organs at risk (OARs) within tolerance limits while minimizing the risk of creating hotspots near critical structures. In this work, we compare dosimetric results for planning with and without this auxiliary volume.

METHODS AND MATERIALS

The ITV_120 optimization structure was defined as a sub-volume of the ITV intended to receive 120% of the prescription dose. This structure was created by cropping out the OARs adjacent to the ITV with a 2-mm margin (see Figs 1 and 2). Depending on the tumor location these OARs may include the proximal bronchial tree (PBT), trachea, esophagus, great vessels, spinal cord, and brachial plexus.

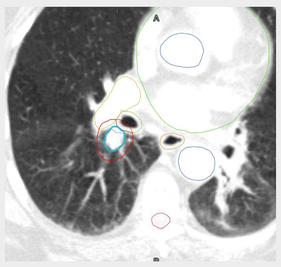

Figure 1. ITV highlighted (cyan).

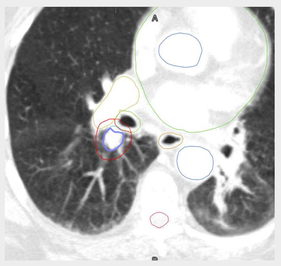

Figure 2. ITV_120 highlighted (purple).

The template was created based on the goals and tolerances provided by the attending physician. Compliance of the adjacent OAR dose constraints was prioritized over PTV coverage (the PTV coverage for the plans generated in Treatment planning system is depicted in Fig 3).

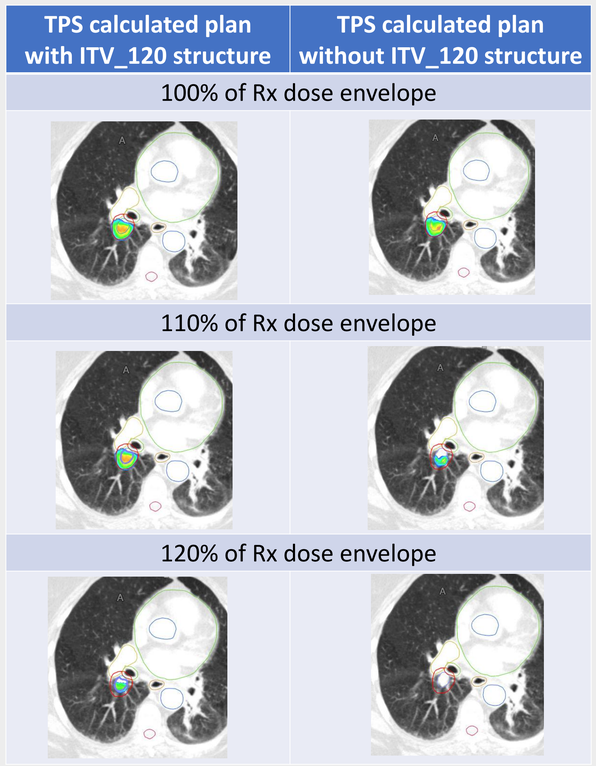

Figure 3. Comparison of plans produced in the TPS using template with and without ITV_120 optimization structure. Contours: PTV and PTV_Eval (PTV excluding PBT) are shown in red; ITV- in cyan, ITV_120- in purple.

Plans generated during adaptive sessions on the machine using the treatment planning template, with and without incorporation of the ITV_120 structure during optimization, were evaluated and compared using standard dosimetric metrics.

RESULTS

With the ITV_120 optimization structure in place, the adaptive plan delivered dose to ITV D98% was 7.78 ± 0.38 Gy (7 fractions), which is 3.7% higher than the prescription dose of 7.5 Gy/fx, whereas without it, it was only 7.23 Gy (1 fraction). Fig.4 and Fig.5 provide the overview of the results.

Dose D99% of the PTV_eval (PTV excluding OARs) for the adaptive plan without the ITV_120 in the template was 6.57 Gy, and with the ITV_120 present it was 6.53±0.15 Gy on average.

The dose to the adjacent OARs: proximal bronchial tree and great vessels of the heart was 7.32 Gy and 6.77 Gy, respectively, for the template without the ITV_120, and 7.16 ± 0.13 Gy and 6.70 ± 0.10 Gy, respectively, for the template with the ITV_120.

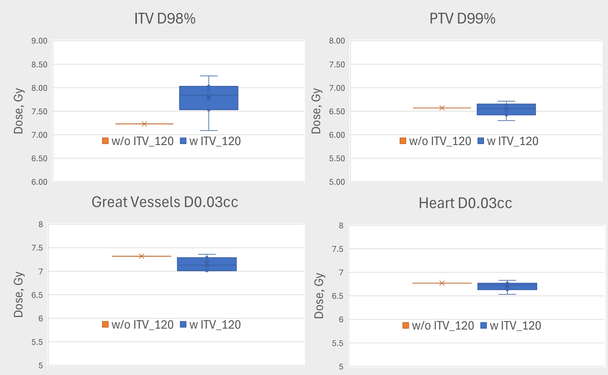

Figure 4. Comparison of the target coverage and dose to the adjacent OARs for the adaptive plans generated on the machine.

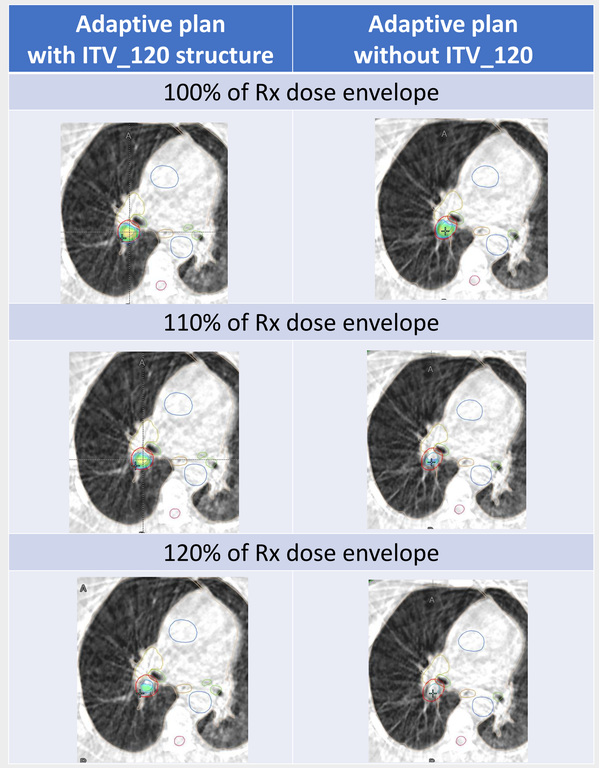

Figure 5. Comparison of adaptive plans produced on the machine using template with and without Auxiliary ITV_120 structure (1 fx). Contours: PTV and PTV_Eval (PTV excluding PBT)- red; ITV-cyan.

DISCUSSION

- The adaptive plans with the ITV_120 optimization structure show substantial benefits in terms of ITV coverage with enhanced dose boost and are comparable in D99% of PTV_eval coverage with the adaptive plan without the ITV_120 structure in place.
- The incorporation of the ITV_120 optimization structure enables spatial control of hotspot placement, based on the anatomy of the day, directing dose escalation to regions of the ITV that were separated from adjacent organs at risk, and maintaining compliance with OAR constraints.
- Data from plans generated without the ITV_120 optimization structure remain limited, as very early observations revealed that this template does not produce hot enough plans desired for hypo-fractionated regime.

CONCLUSIONS

Preliminary results indicate that incorporating the optimization structure ITV_120 into the 8-fraction hypo-fractionated lung adaptive treatment template enables intentional dose escalation within the ITV, concentrated hotspot placement in regions spatially separated from adjacent OARs, and improved compliance with OAR dose tolerance constraints.

REFERENCES

1. Yan M, Louie AV, Kotecha R, et al. Stereotactic body radiotherapy for ultra-central lung tumors: A systematic review and meta-analysis and International Stereotactic Radiosurgery Society practice guidelines. Lung Cancer. 2023;182:107281.
2. Regnery S, Buchele C, Weykamp F, et al. Adaptive MR-Guided Stereotactic Radiotherapy is Beneficial for Ablative Treatment of Lung Tumors in High-Risk Locations. Front Oncol. 2022;11:757031.