Stony Brook School of Health Professions

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Comparative Dosimetric and Efficiency Parameters Utilizing RapidPlan for Knowledge-Based Planning in Cervical, Thoracic, and Abdominal Esophageal Cancer

Background

Esophageal cancer poses challenges for radiation therapy due to its location and proximity to critical organs namely the lungs, heart, and liver. Treatment planning must balance target coverage with organ constraints, often impacting plan quality and efficiency. RapidPlan (RP), a knowledge-based tool, offers a data-driven approach to improve consistency and streamline planning. At Mount Sinai, a RP model was developed and validated for esophageal cancer patients, however there is a need to investigate tradeoffs between quality and efficiency for this model. This study compares RP with conventional planning, evaluating target coverage, dose uniformity, organ sparing, and planning efficiency.

Purpose

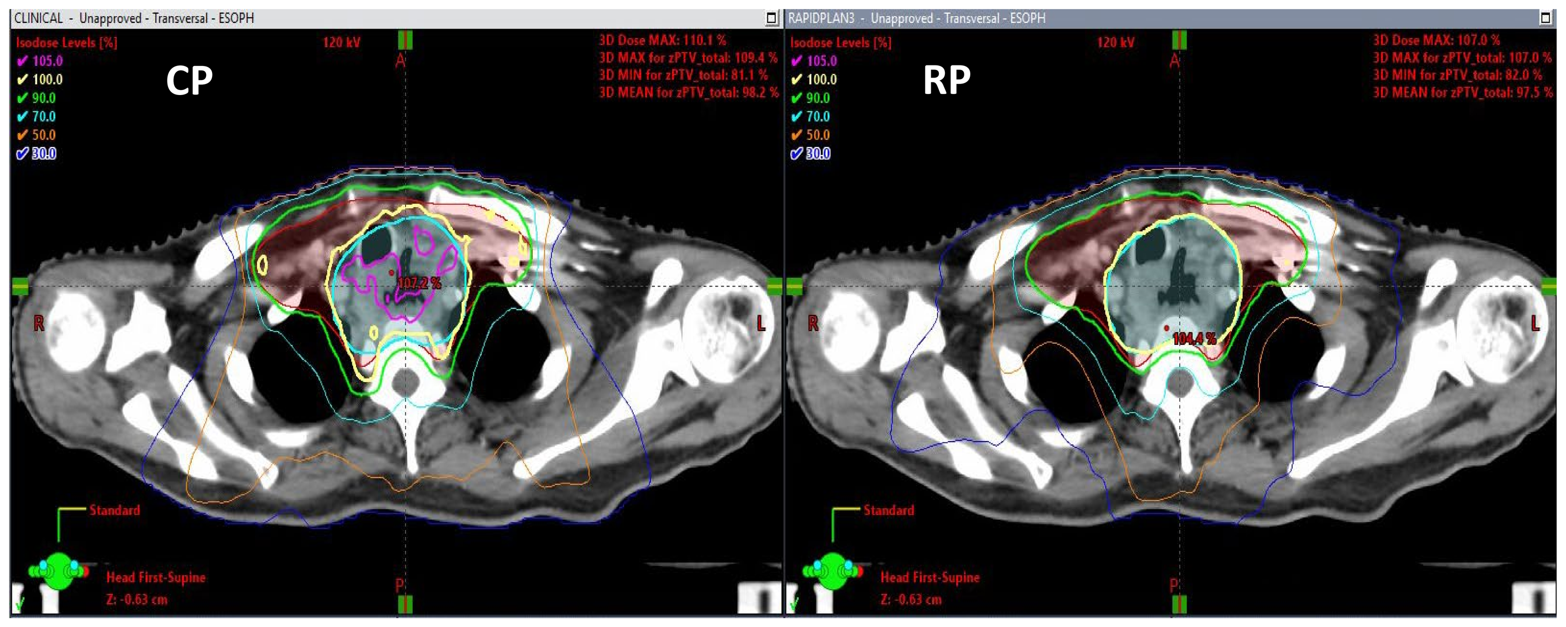
This study aimed to evaluate whether RP can improve or produce comparable dosimetric results while improving planning efficiency compared to standard clinical plans, specifically, assessing the impact on target coverage, dose uniformity, critical organ sparing, and overall planning time.

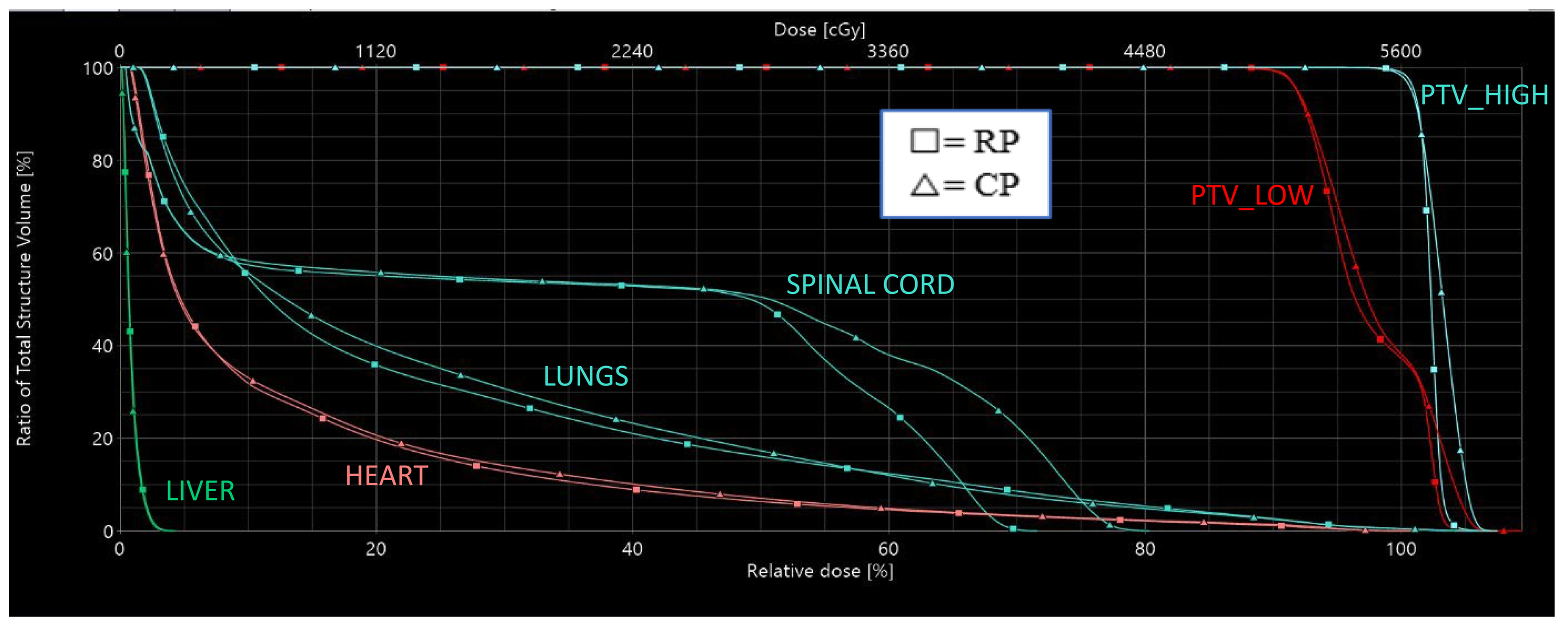
Materials and Methods

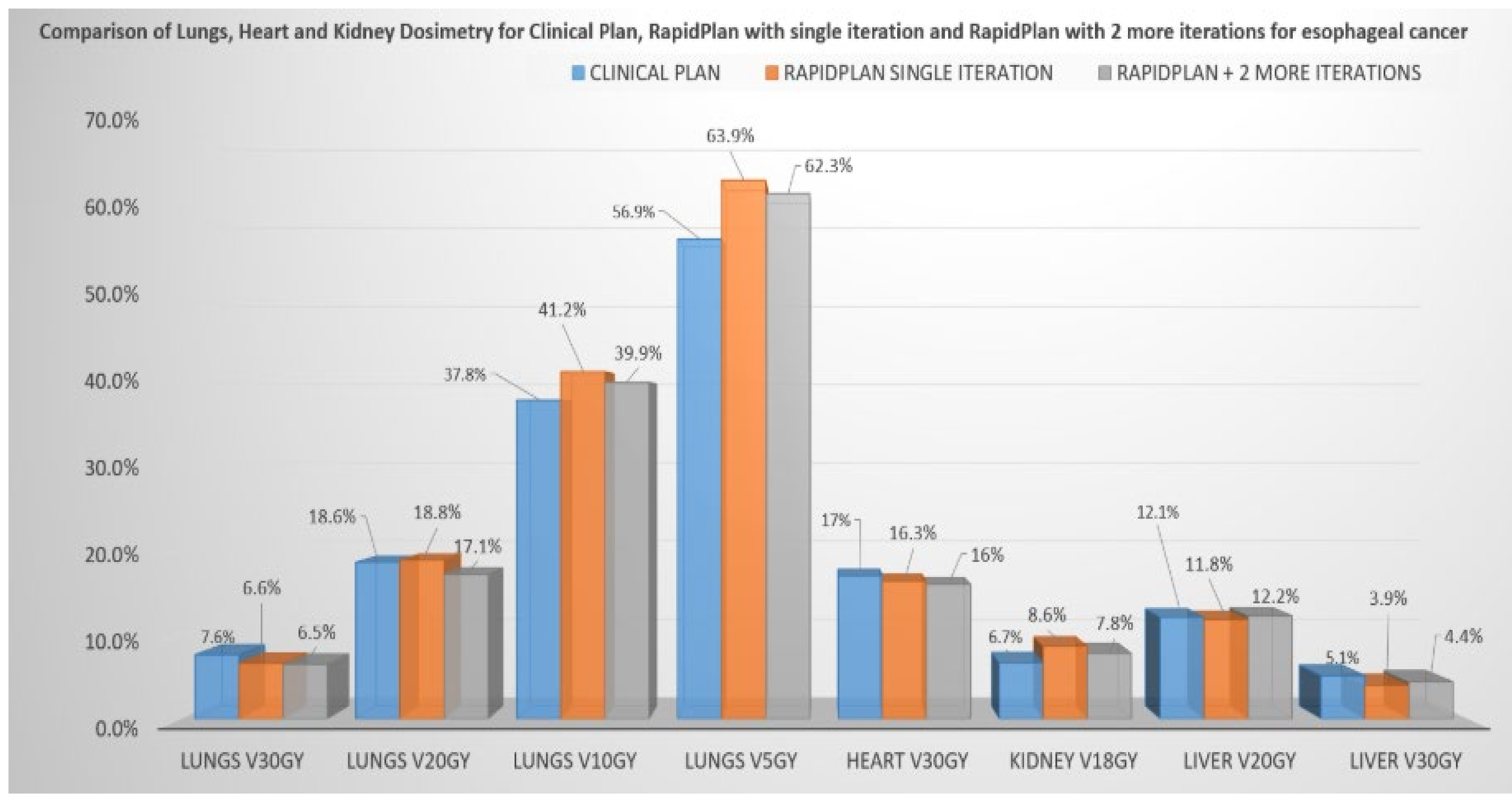
A RapidPlan model was developed from 45 patients treated with Volumetric Modulated Arc Therapy (VMAT), by replanning the cases as required to reduce the V105%(cc) as much as feasible. 15 test patients with esophageal tumors that were not included in training the model underwent retrospective treatment planning using RapidPlan while evaluating clinical efficiency data such as structure assignment time, time taken to contour any additional optimization structures, number of iterations, and total optimization time, along with dosimetric parameters on coverage and critical organ doses. Significance testing was performed using the Wilcoxon sign-rank test for non-parametric statistics. Since previous investigations have confirmed the benefit of not using avoidance sectors, all of our plans using RapidPlan did not use the same.

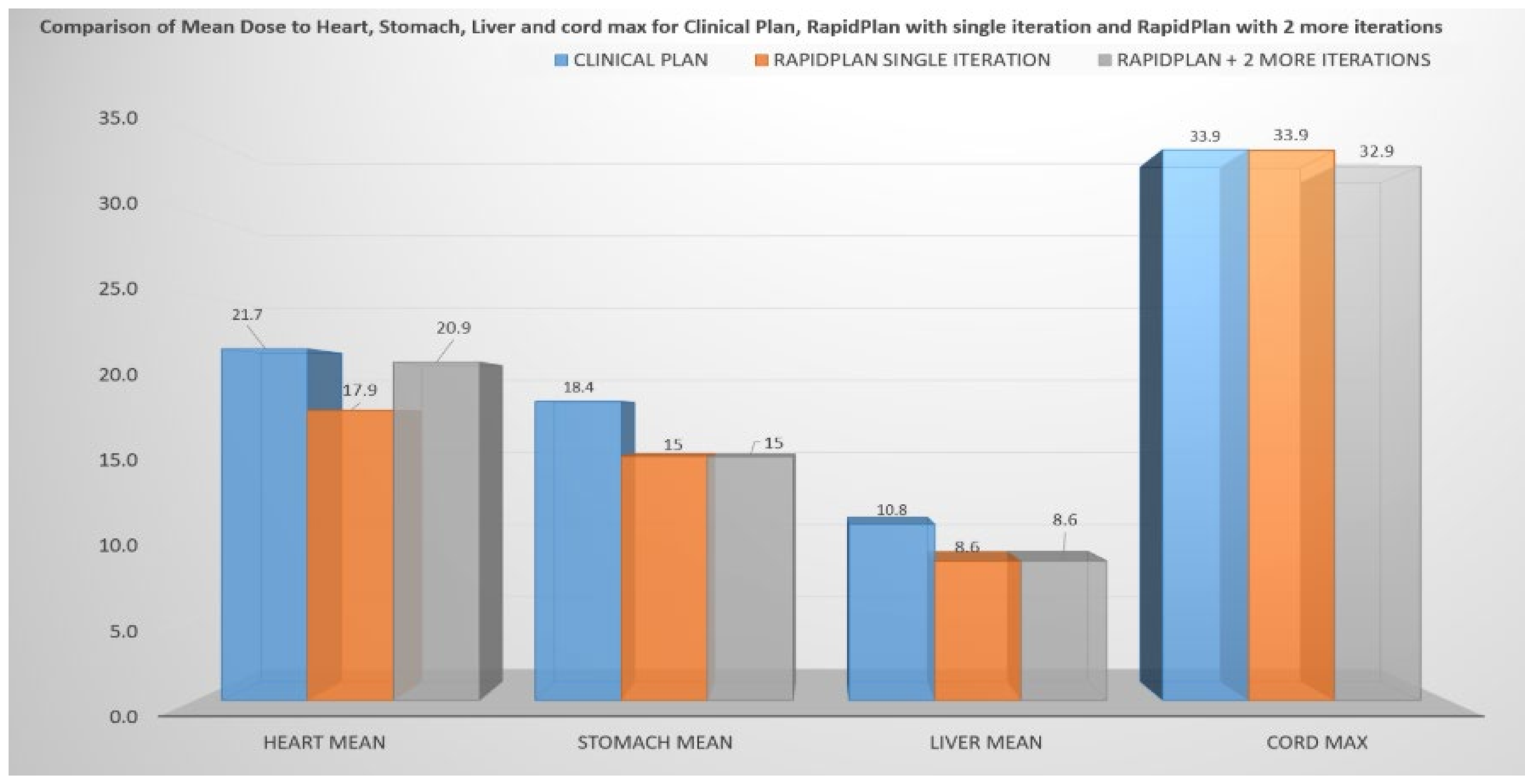
Results

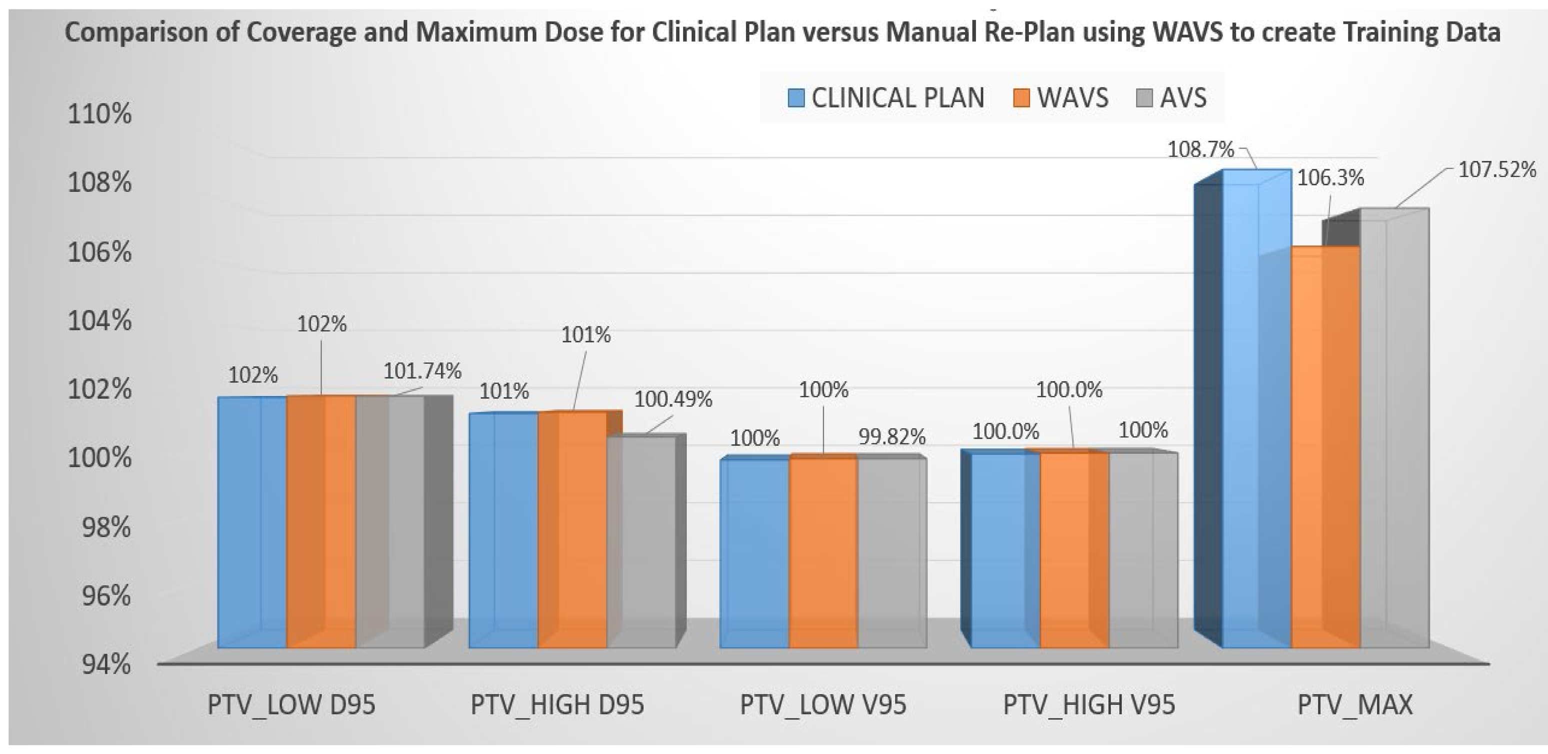
For comparable target coverage and plan homogeneity, RP significantly ($p<0.05$) improved sparing of the heart, liver, and stomach. After the first iteration, the mean dose decreased by an average of 3.76 Gy for the heart, 3.43 Gy for the stomach, and 2.24Gy for the liver. Similar reductions were observed after the final iteration, apart from the heart, which received a slightly higher dose due to prioritization of lung sparing. Lung dose in the RP plans was comparable to the clinical plans, with respect to V30, V20, V10, and V5 respectively, after the first iteration. The average total optimization time using RP was 17.4 minutes across all iterations, with a median of two additional iterations per case, requiring approximately 5 minutes per iteration. Including structure assignment and optimization structure creation, the estimated total planning time per RP plan was 22 minutes following receipt of contours. Median number of additional optimization structures required in the clinical workflow was 11 compared to 1 when using RapidPlan.











Parameter	Value
Mean time for model structure assignment (mins)	2.6 ± 1.2
Mean time for additional optimization structure creation (mins)	2.2 ± 1.1
Median number of additional optimization structures	1
Median number of additional iterations	2
Mean RapidPlan optimization time (total)	17.4 ± 14
Mean Optimization time per iteration (with hold)	5.8 ± 4.6
Mean Optimization time per iteration (without hold)	4.5 ± 1.3
% plans meeting goal OAR constraints in single iteration	82
% plans meeting acceptable OAR constraints in single iteration	95
% plans meeting goal coverage constraints in single iteration (V100 >=97%)	100
% plans meeting acceptable coverage constraints in single iteration (V100 >=95%)	100

Comparison of Conformity Index

Plan	CI
CP	1.26±0.38
RapidPlan, WAVS	1.20±0.23

Comparison of V105% (cc)

Plan	V105% (cc)
CP	54.7 ± 44.5
RapidPlan, WAVS	2.8 ± 4.6

Conclusion

This study demonstrated that the RP model improved dosimetric results and planning efficiency for esophageal cancer treatment compared with standard clinical planning approach. Since this was a retrospective study, data for how long it took for the clinical plans was not documented. However, RapidPlan reduced the number of additional optimization structures to one fifth of the clinical plan. For comparable target coverage , RP enhanced sparing of critical organs, including the lungs, heart, and liver. It improved plan conformity as well as the volume of the V105%(cc) by a factor of 20. Additionally, RP proved to have a streamlined planning process, maintaining consistent plan quality. These results support the use of knowledge-based planning to address the challenges of elongated target volumes and proximity to multiple organs at risk, ultimately improving both plan quality and efficiency in esophageal cancer radiotherapy.

Future Developments

This model has only taken 1–2 PTV dose levels into consideration. For future experiments, the model could be extended to include more than two dose levels. In addition, it would be worthwhile to investigate whether training the model with plans using gEUD would yield similar outcomes.

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