Stony Brook School of Health Professions

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Evaluating Rectal and Anal RapidPlan Models for Clinical Use: Can RapidPlan Generate a Clinically Acceptable Plan Under 3 Iterations?

Background

Planning for rectal and anal cancer cases can be challenging, as the PTV volume and shape vary depending on the extent and type of lymph node involvement. Additionally, the PTV is often surrounded by multiple organs at risk (OARs), including the bladder, femoral heads, small and large bowel, and genitalia. RapidPlan (RP) is a knowledge-based planning model trained on high-quality treatment plans to pursue the goal of improving plan quality and optimizing dosimetric parameters. At our institution, models for rectal and anal cancer were developed and tested for dosimetric plan quality with respect to the clinical plan, however the tradeoffs between efficiency and plan quality was not evaluated.

Purpose

The purpose of this retrospective study is to evaluate the effectiveness of a RapidPlan (RP) model in improving planning efficiency and reducing the time required to achieve a clinically acceptable plan of equivalent quality for physician approval.

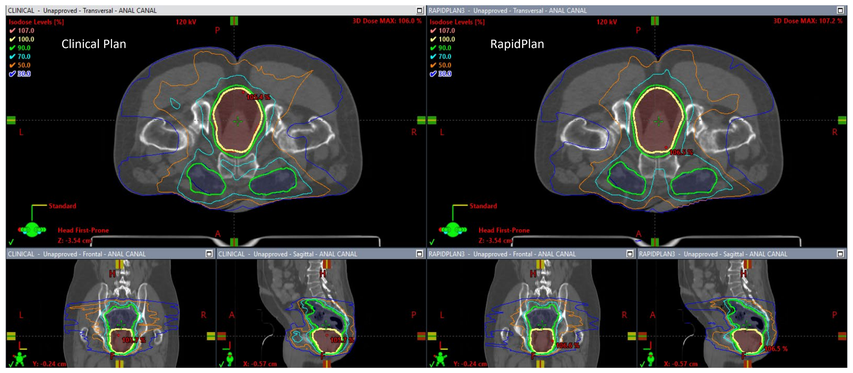
Materials and Methods

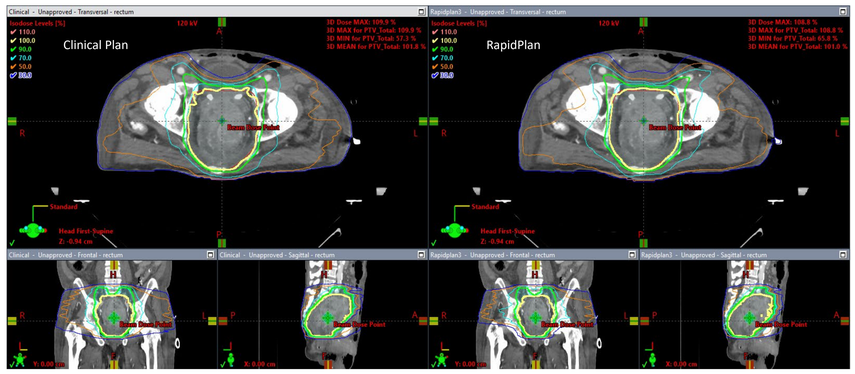
The RP model was developed using a dataset including a total of 92 patient cases treated with volumetric modulated arc therapy (VMAT) to train anal and rectal models capable of estimating dose volume histograms (DVHs) for OARs in rectal and anal cancer cases. To evaluate the effectiveness of the model, 11 anal test cases and 12 rectal test cases not part of the training dataset were randomly selected and replanned. The results from the first iteration and the final optimized plans using RP were then compared with the respective original clinical plans to assess differences in dosimetric plan quality. Significant testing was performed using the Wilcoxon sigh-rank for non-parametric statistics.

Results

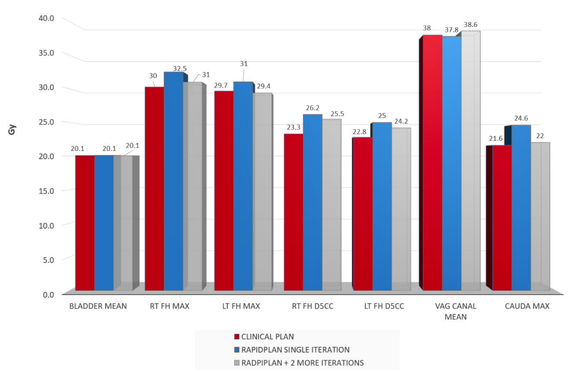
In the analysis of anal cases, evaluation of target coverage demonstrated that, on average, the clinical plans, single-iteration RP plans, and RP plans with two or more iterations produced comparable coverage and hotspot values. Single-iteration RP planning proved insignificant differences ($p>0.05$) in doses to priority organs at risk (OARs), including the bladder, genitalia, and vaginal canal. Doses to the large bowel, small bowel, and femoral heads were also comparable ($p>0.05$). Median number of extra iterations needed was 2 to help customize the plans to the respective clinical result, although this difference was also found to be statistically insignificant. Similarly, rectal cases proved comparable target coverage and hotspot values across clinical plans and RP iterations. In terms of OAR sparing, the model in a single iteration achieved comparable doses to the organs at risk (OARs) as the respective clinical plan ($p>0.05$).

With subsequent iterations, further reductions were observed to customize the plan to the respective clinical result, although found to be statistically insignificant. For **anal cases**, the mean time for model structure assignment was 3.6 minutes, with an additional 7.6 minutes for optimization structure creation. Plans required a median of 5 additional structures and 2 iterations, with a total optimization time of about 45 minutes. Most plans met OAR constraints in a single iteration (95%), with 98.4% achieving acceptable constraints, and all plans met coverage goals. For **rectal cases**, the mean structure assignment time was 5.1 minutes and 3.4 minutes for additional optimization structures. Plans required a median of 2 additional structures and 2 iterations, with a total optimization time of about 43 minutes. OAR constraints were met in a single iteration in 90% of plans, with 96% achieving acceptable constraints, and all plans met coverage requirements.

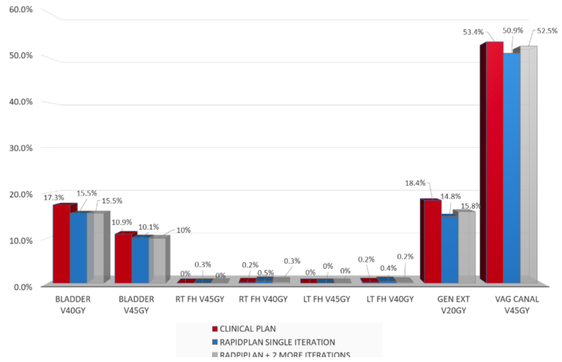




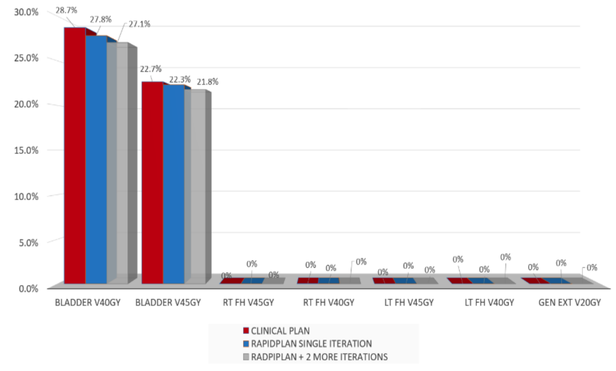
Doses to the Bladder, Femoral Heads, Vaginal Canal and Cauda for Clinical Plan, RapidPlan single iteration and RapidPlan + 2 more iterations in Anal Cancer Patients



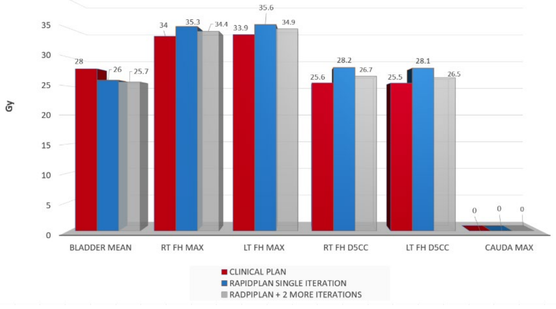
Bladder, Femoral Head, Genitalia and Vaginal Canal Doses for Clinical Plan, RapidPlan single iteration and RapidPlan + 2 more iterations in Anal Cancer Patients



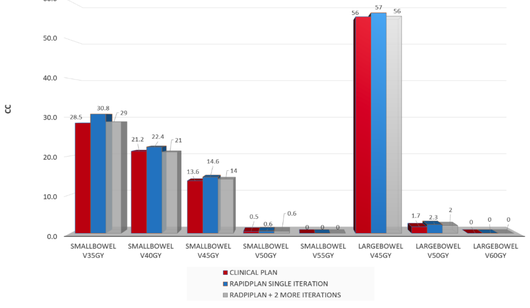
Bladder, Femoral Head and Genitalia Doses for Clinical Plan, RapidPlan single iteration and RapidPlan + 2 more iterations in Rectal Cancer Patients



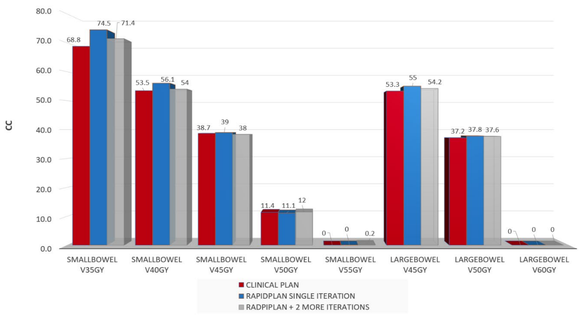
Doses to the Bladder, Femoral Heads and Cauda for Clinical Plan, RapidPlan single iteration and RapidPlan + 2 more iterations in Rectal Cancer Patients



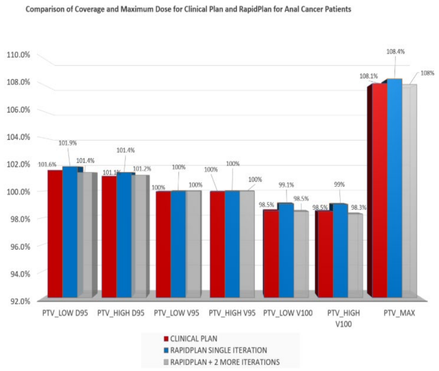
Large and Small Bowel Doses for Clinical Plan, RapidPlan single iteration and RapidPlan + 2 more iterations in Anal Cancer Patients



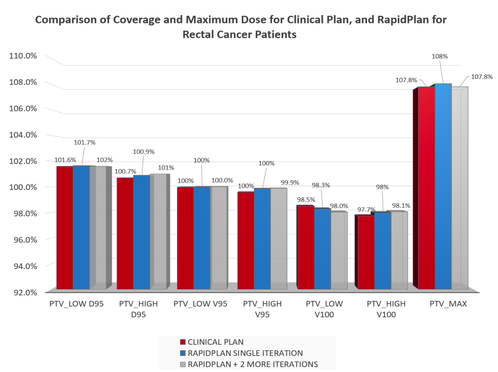
Large and Small Bowel Doses for Clinical Plan, RapidPlan single iteration and RapidPlan + 2 more iterations in Rectal Cancer Patients



Comparison of Coverage and Maximum Dose for Clinical Plan and RapidPlan for Anal Cancer Patients

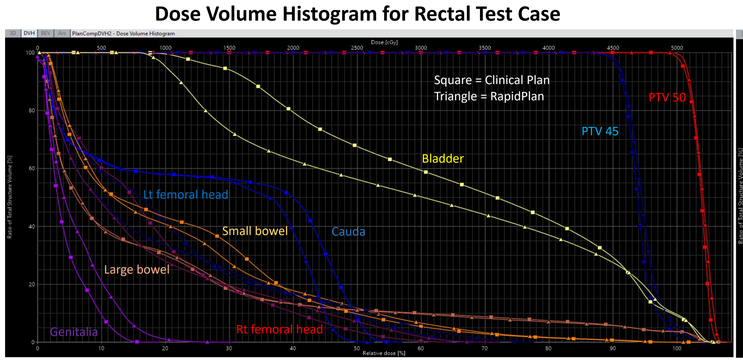


Comparison of Coverage and Maximum Dose for Clinical Plan, and RapidPlan for Rectal Cancer Patients

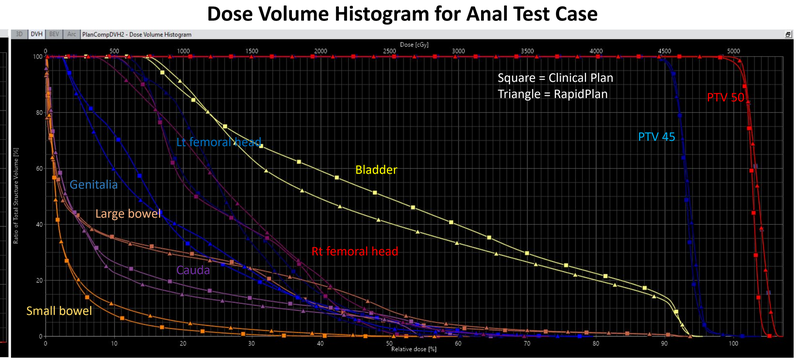


Parameter	Anal	Rectal
Mean time for model structure assigment (mins)	3.6+/-1.8	5.1+/-1.2
Mean time for additional optimization structure creation (mins)	7.6+/-5.5	3.4+/-2
Median number of additional optimization structures	5	2
Median number of additional iterations	2	2
Mean RapidPlan optimization time (total)	45+/-16.5	43+/-15.4
Mean Optimization time per iteration (with hold)	13.3+/-6.3	14+/-5.5
Mean Optimization time per iteration (without hold)	4.8+/-0.3	6.5+/-0.8
% plans meeting goal OAR constraints in single iteration	95%	90%
% plans meeting acceptable OAR constraints in single iteration	98.4%	96%
% plans meeting goal coverage constraints in single iteration (V100 >=97%)	100%	100.00%
% plans meeting acceptable coverage constraints in single iteration (V100 >=95%)	100%	100.00%

Dose Volume Histogram for Rectal Test Case



Dose Volume Histogram for Anal Test Case



Conclusion

Overall, the implementation of the RP model improved planning efficiency for both anal and rectal cases by reducing the time required to generate clinically acceptable plans within 3 iterations while keeping consistent plan quality. The RP approach minimized the need for additional optimization structures without compromising target coverage or critical organ sparing in comparison to the clinical plan.

These findings support the use of RP to improve consistency and workflow efficiency in radiation therapy planning. Therefore, RP serves as an effective tool for establishing a strong initial plan and facilitating the overall planning process.

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