RapidPlan Development of VMAT Plans for Cervical Cancer Patients in Low- and Middle-Income Countries

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Introduction

- Cervical cancer has a high incidence and mortality rate in low- and middle-income countries (LMICs) largely due to limited resources and insufficient staffing.
- Knowledge-based planning (KBP) could ease the burden of staff insufficiencies by creating treatable EBRT plans with low levels of planner intervention.
- Aim: To use Varian's KBP system (RapidPlan™) to develop a model capable of producing volumetric modulated arc therapy (VMAT) plans for cervical cancer patients.

Methods & Materials

- All cervical cancer patient plans used in this study were previously planned and treated at MD Anderson Cancer Center (MDACC) using IMRT or VMAT techniques.

Data from 46 patient plans were extracted for model training.

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Outliers were eliminated, objectives were adjusted, and model configuration was completed.

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32 separate patients were selected for the validation of the model.

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Configured model was applied to the validation plans.

Model Structures and Objectives				
ID		Vol [%]	Dose	Priority
PTV High	Upper	0	102%	Generated
	Lower	100	100%	Generated
Bladder	Upper (fixed dose, generated vol.)	Generated	40Gy	Generated
	Upper (fixed dose, generated vol.)	Generated	30Gy	Generated
	Mean	N/A	Generated	Generated
	Line (preferring target)	Generated	Generated	Generated
Bowel	Upper	0	51.5Gy	Generated
	Upper (fixed dose, generated vol.)	Generated	50Gy	Generated
	Upper (fixed dose, generated vol.)	Generated	40Gy	Generated
	Upper (fixed dose, generated vol.)	Generated	30Gy	Generated
	Line (preferring target)	Generated	Generated	Generated
Rectum	Upper (fixed dose, generated vol.)	Generated	40Gy	Generated
	Upper (fixed dose, generated vol.)	Generated	30Gy	Generated
	Mean	N/A	Generated	Generated
	Line (preferring target)	Generated	Generated	Generated

Table 1. Automated and manual objectives used in the RapidPlan™ model.

Results

- A TOST test showed that the p-values for the PTV_High $D_{95.0\%}$ ($p<0.001$), rectum V_{30Gy} ($p=0.039$), and mean dose to the bladder ($p=0.0014$), rectum ($p=0.025$), and bowel ($p=0.006$) were statistically significant within a 5% equivalence margin thereby providing strong evidence of equivalence.
- Based on this statistical analysis, it was determined that the model was capable of generating treatable VMAT plans for cervical cancer patients.

	Validation plans (n=32)		Clinical plans (n=32)		Paired differences (Validation vs. Clinical)	
Variable	Mean	Std dev	Mean	Std dev	Mean	Std dev
PTV_High D95.0%[Gy]	48.4Gy	2.6Gy	48.5Gy	3.0Gy	0.1Gy	1.6Gy
Bladder V30.0Gy[%]	76.4%	16.6%	79.6%	14.5%	3.2%	9.3%
Bowel V30.0Gy[%]	25.3%	11.0%	25.3%	11.3%	-0.1%	4.1%
Rectum V30.0Gy[%]	84.7%	12.5%	86.7%	14.3%	1.9%	7.4%
Bladder Mean[Gy]	38.9Gy	4.0Gy	39.8Gy	3.9Gy	0.9Gy	1.9Gy
Bowel Mean[Gy]	21.5Gy	4.6Gy	21.6Gy	5.0Gy	0.2Gy	1.9Gy
Rectum Mean[Gy]	40.3Gy	4.8Gy	41.6Gy	5.2Gy	1.2Gy	2.3Gy

Table 2. Summary of the mean doses and standard deviations for the PTV_High and OARs.

Paired TOST test		
Variable	Equivalence margin	p-value
PTV_High D95.0%[Gy]	2.4Gy	< 0.001***
Bladder V30.0Gy[%]	4.0%	0.31
Bowel V30.0Gy[%]	1.3%	0.058
Rectum V30.0Gy[%]	4.3%	0.039*
Bladder Mean[Gy]	2.0Gy	0.0014**
Bowel Mean[Gy]	1.1Gy	0.006**
Rectum Mean[Gy]	2.1Gy	0.025*

Table 3. TOST Equivalence Test Results for PTV_High and OARs.

- A radiation oncologist at MDACC reviewed 10 out of the 32 plans generated by the model. Based on MDACC standards, 9 out of the 10 plans were treatable with minor adjustments to normalization.

Structure (dose constraint)	Met constraints	Did not meet constraints	No structures	Total
Bladder (V45Gy <50%)	15	17	0	32
Bowel (V40Gy <30%)	26	5	1	32
Rectum (V45Gy <80%)	28	4	0	32

Table 4. Number of validation plans that met the bladder, bowel, and rectum constraints.

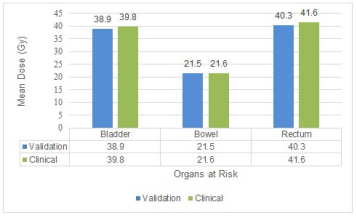

Fig. 1. Mean dose (Gy) to the OARs for the validation and clinical plans.

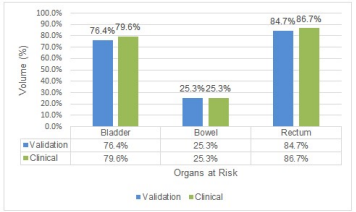

Fig. 2 . Percentage of the OAR volume receiving 30Gy for validation and clinical plans.

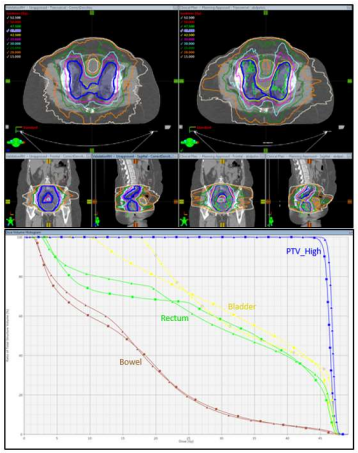

Fig. 3. Validation plan ■ vs. Clinical plan ▲ (one dose level): dose distribution and DVH for the PTV_High and OARs.

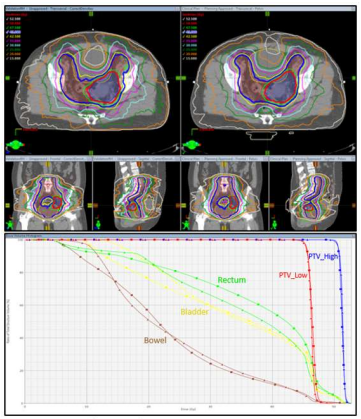

Fig. 4. Validation plan ■ vs. Clinical plan ▲ (two dose levels): dose distribution and DVH for the PTV_High and OARs.

Discussion

- This study showed that the RapidPlan™ model produced treatment plans similar to the previously treated clinical plans in a single optimization with minimal adjustments to normalization.
- A limitation to the model was that planning structures (aside from a pPTV) were not created for the validation plans.
- Since all patients were randomly selected, cervical cancer stages were not taken into consideration during the model configuration.
- Patients were treated to different prescriptions doses, with some prescribed to one dose level while others were prescribed to two dose levels. This could have affected the model's capabilities.

Conclusion

- The RapidPlan™ model configured, trained, and validated by this study successfully generated radiotherapy plans for cervical cancer patients. In its current state, the model is capable of generating plans similar to the previously treated clinical plans, making it a viable tool for treating cervical cancer patients in LMICs. In the future, the model could be refined in order to produce plans that are superior to manually generated plans. The implementation of the model would ultimately streamline the treatment planning process and improve access to high quality radiotherapy for cervical cancer patients around the world.

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