

Volumetric-Modulated Arc Therapy as an Alternative to High Dose Rate Interstitial Brachytherapy: A Feasibility Study

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INTRODUCTION

- High dose rate (HDR) brachytherapy is commonly used to treat gynecological (GYN) malignancies with extensive parametrial involvement.
- However, it is invasive, resource-demanding, and may not be applicable to patients unqualified for anesthesia.
- Volumetric-modulated arc therapy (VMAT) has been shown to be a feasible alternative for HDR patients with vaginal cuff^{1,2} and tandem and ovoid³ treatment;
- However, such feasibility has not been investigated in GYN patients needing extensive interstitial brachytherapy.

AIM

- To investigate the feasibility of volumetric-modulated arc therapy (VMAT) as an alternative to HDR interstitial brachytherapy.

METHODS

- Four GYN patients treated with HDR interstitial brachytherapy using the Syed template studied to compare them with VMAT plans
- Clinically-treated HDR Syed plans generated in Oncentra® brachy

VMAT Planning

- The HDR plan and associated CT images with incomplete body (Fig. 1) imported into the RayStation
- A second set of CT images with complete body scan (Fig. 1) used for external beam radiotherapy imported into RayStation
- Rigid registration performed between these two CT image sets (Fig. 1)
- Complete body contour created and copied to the HDR CT set, followed by density override of the missing body contour to muscle
- A planning target volume (PTV) was generated by a 3-mm expansion to the high-risk clinical target volume (HRCTV).

Planning Workflow

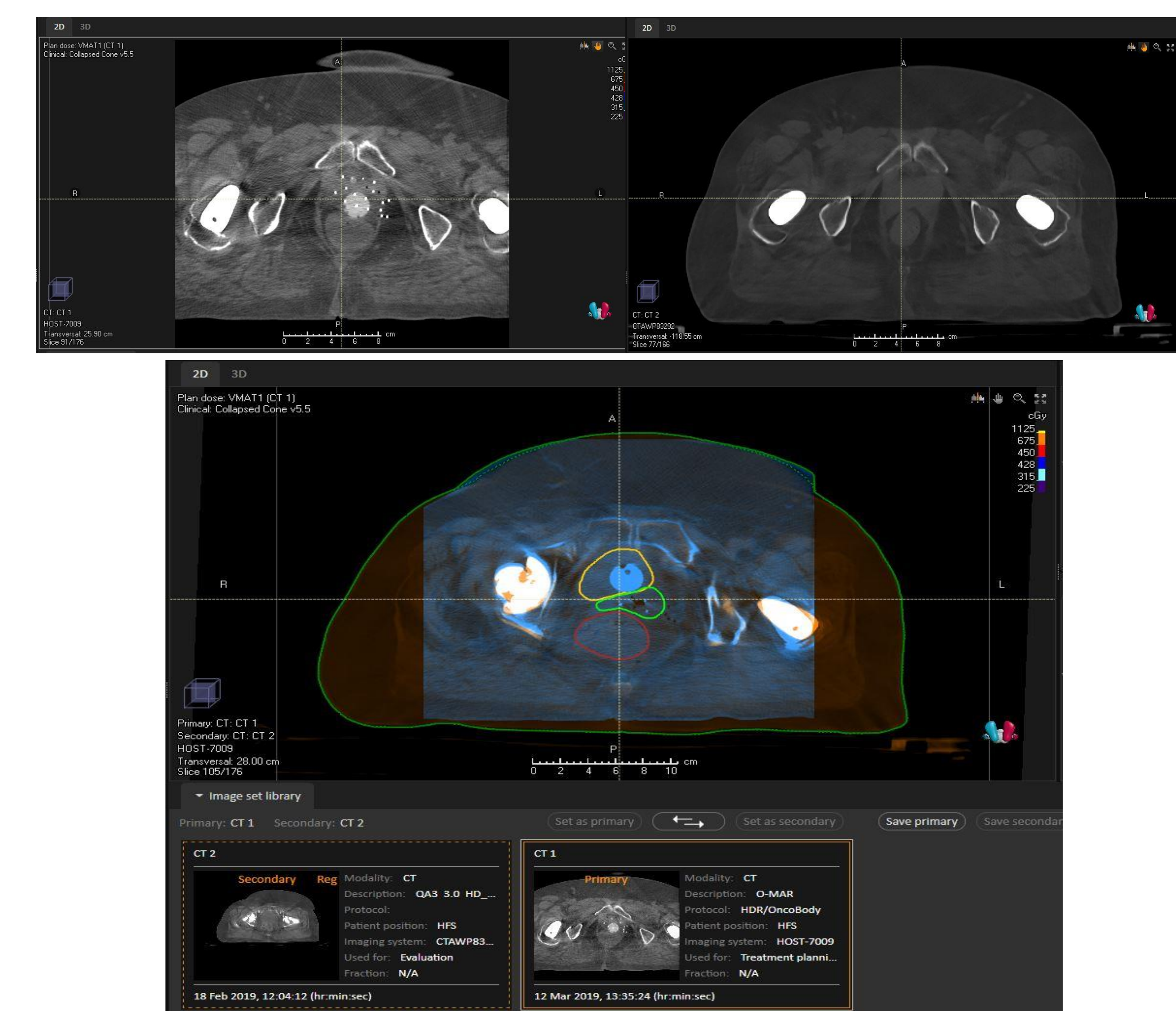
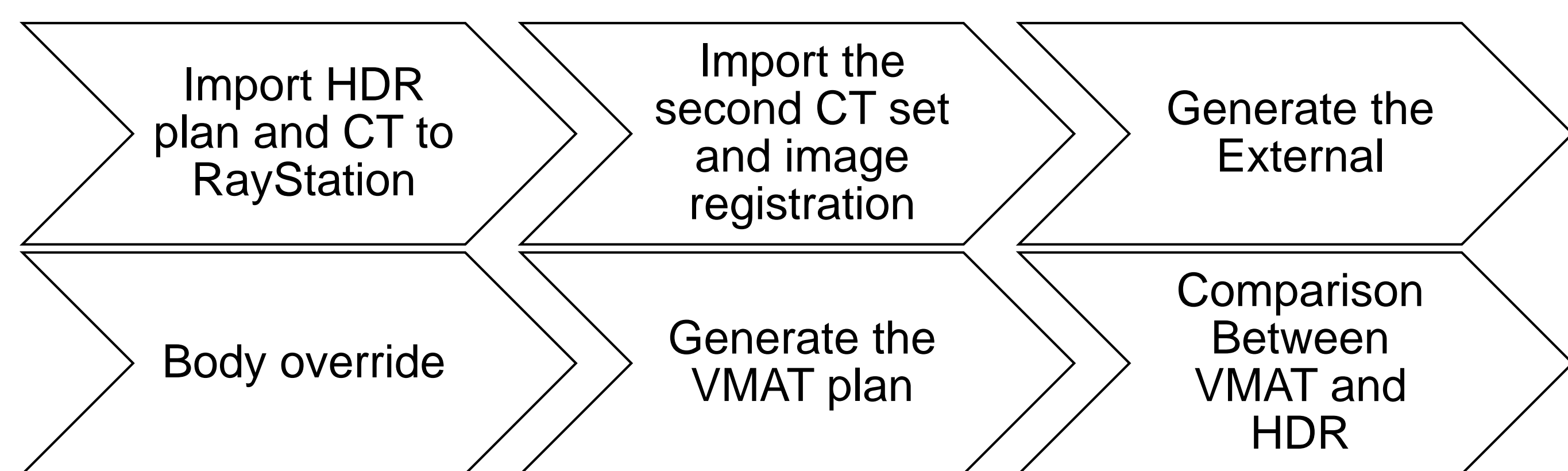


Figure 1. Partial and whole-body CT images, and their fusion with body contour shown.

METHODS (CONTINUED)

Planning Arcs

- Two full arcs used in the VMAT plans as shown in Fig. 2.

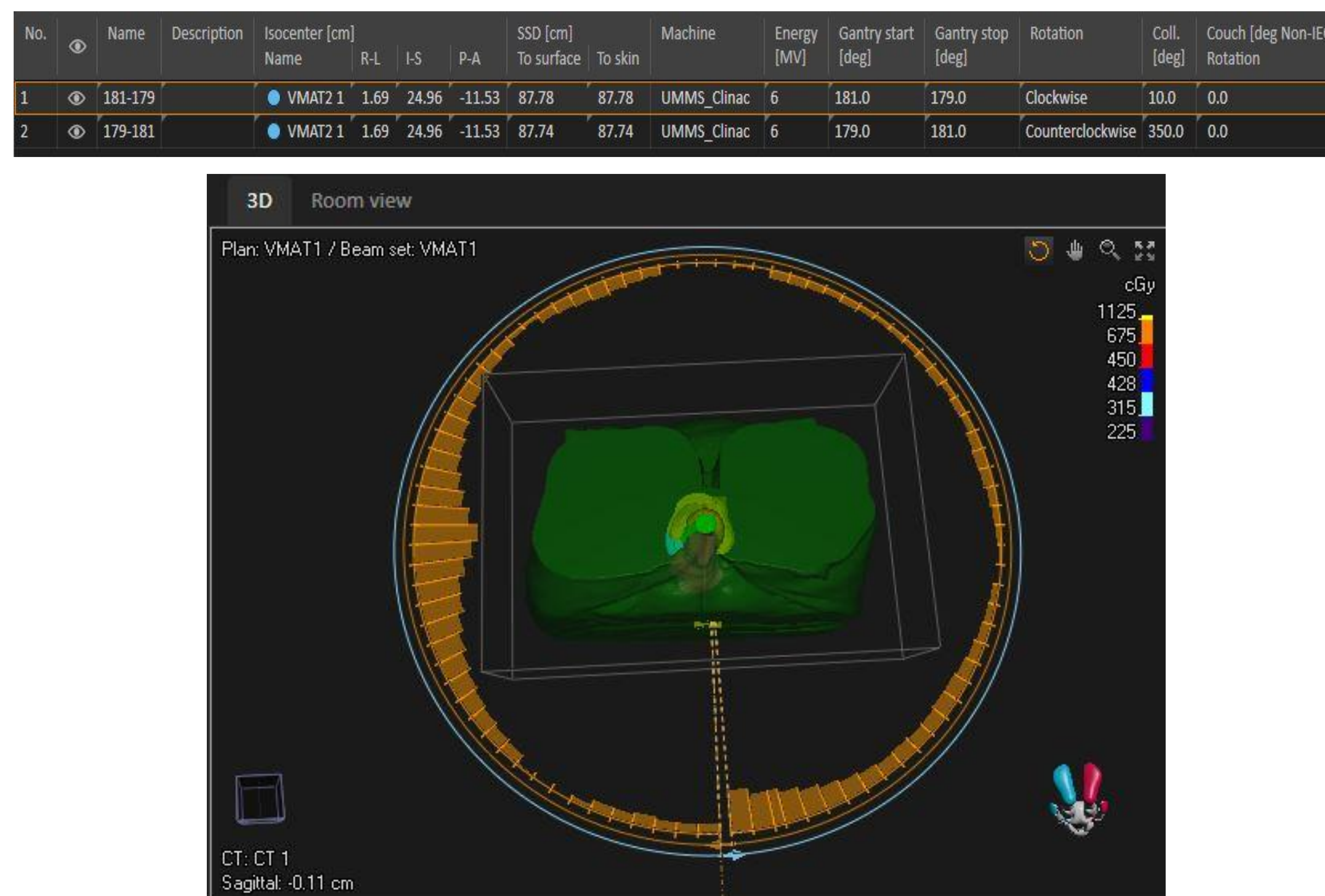


Figure 2. The VMAT plan contains two full arcs and a 3D view of one arc is shown.

Planning Objectives

- External dose fall-off at low dose distance used to ensure rapid dose fall-off
- Min DVH objective to ensure 99% of the HRCTV and 95% of the PTV covered by 95% of the prescription dose
- Min and Max DVH objectives used to achieve the HRCTV V150% and V250% in the HDR plan
- Max equivalent uniform dose (EUD) with the parameter A at 3 for sparing OARs

Function	Constraint	Dose	ROI	Description	Robust	Weight	Value
Physical composite objective							
Dose fall-off							
Plan	External			Dose fall-off [H]450 cGy [L]225 cGy, Low dose distance 0.50 cm		90.00	0.0748
Plan	HRCTV			Min DVH 428 cGy to 99% volume		100.00	0.0000
Plan	PTV			Min DVH 428 cGy to 95% volume		100.00	0.0000
Plan	HRCTV			Min DVH 1125 cGy to 4% volume		100.00	0.0000
Plan	HRCTV			Max DVH 1125 cGy to 6% volume		100.00	0.0000
Plan	HRCTV			Min DVH 675 cGy to 30% volume		100.00	0.0000
Plan	HRCTV			Max DVH 675 cGy to 32% volume		100.00	0.0107
Plan	Bladder			Max EUD 80 cGy, Parameter A 3		1.00	0.0037
Plan	Rectum			Max EUD 120 cGy, Parameter A 3		1.00	0.0024

Figure 3. Sample planning objectives used in VMAT plan optimization.

RESULTS

Plan Comparison

- VMAT plan normalized to ensure 95% of the PTV covered by 95% of the prescription dose
- HRCTV with similar dose heterogeneity as in the HDR plan, but with improved coverage
- Satisfactory OAR sparing with similar bladder dose but slightly higher dose to the rectum

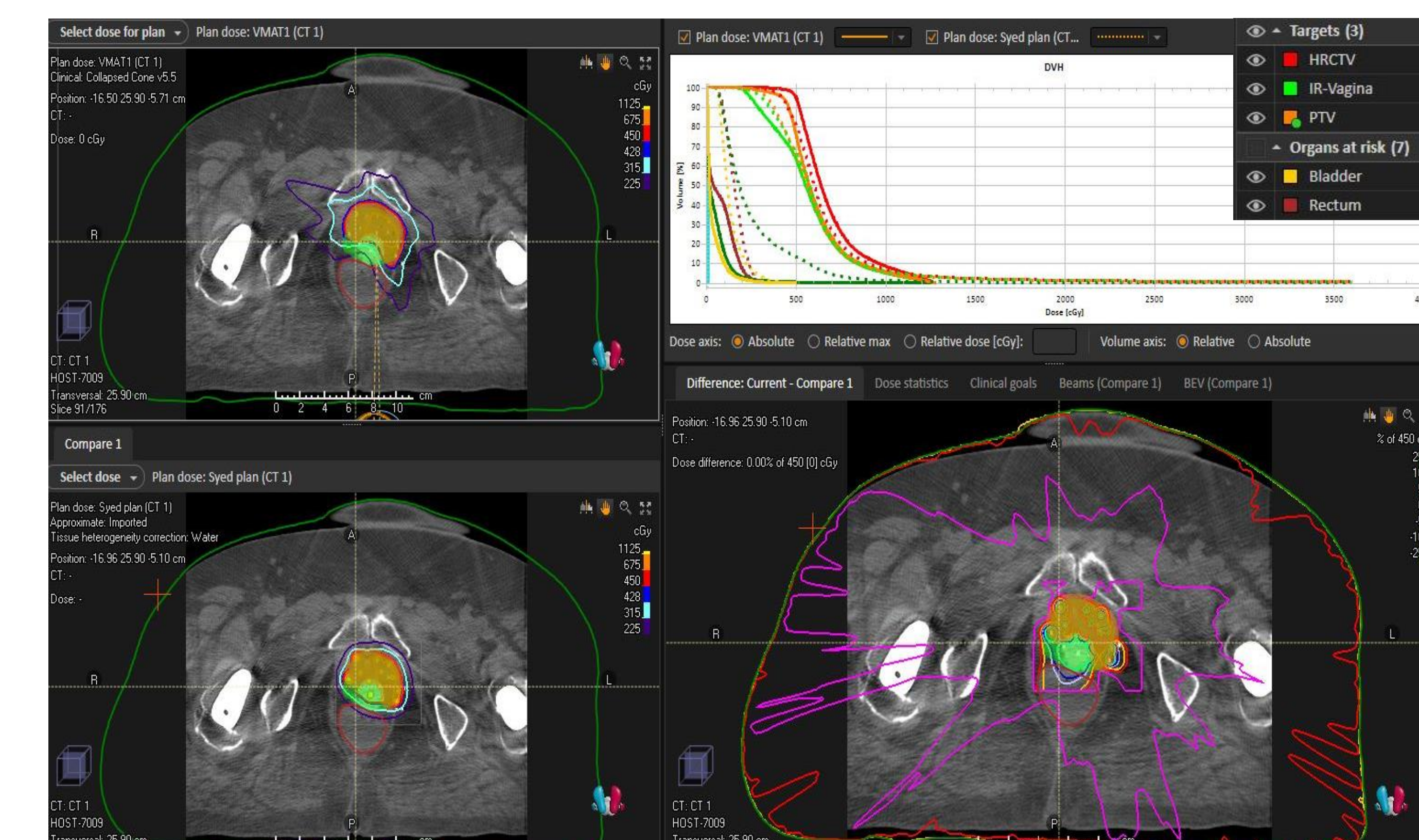


Figure 4. Representative comparison between the VMAT and HDR plans.

RESULTS (CONTINUED)

Statistical Analysis

- Compared to the HDR plan, the VMAT plan offered improved HRCTV V90%, V100%, D90%, and D100% (P<0.05 for all)
- Meanwhile, HRCTV V150% and V250% were similar to those in the HDR plan, ensuring HDR-like dose inhomogeneity
- No statistically significant difference in the bladder D2cc, but the rectum D2cc was significantly larger in the VMAT plan

Table 1. Statistical comparison of the DVH metrics of the VMAT and HDR plans.

Volume	DVH Metric	VMAT (%)	HDR (%)	P Value
HRCTV	V90%	99.9±0.2	96.3±1.0	P=0.008
	V100%	99.4±0.4	92.4±1.1	P<0.001
	D90%	116.5 ±8.9	104.9±2.6	P=0.036
	D100%	87.8±20.6	48.9±4.6	P=0.046
	V150%	55.0±13.1	52.2±16.9	P=0.324
V250%	15.0±9.5	16.9±11.3	P=0.130	
Bladder	D2cc	85.9±25.8	83.3±13.2	P=0.783
Rectum	D2cc	67.3±12.8	55.6±11.4	P=0.023

Values expressed as mean±standard deviation. Statistical comparison conducted using paired student's t test.

DISCUSSION

- HDR is a popular treatment modality for GYN patients, but may not be a feasible option for some GYN patients
- For GYN patients with local diseases, the target size is relatively small and previous studies have demonstrated the capability of VMAT in mimicking HDR dose distribution
- For the first time, we have demonstrated the feasibility of using a VMAT plan to generate HDR-like dose distribution for GYN patients with extensive parametrial involvement
- Unlike HDR treatment, VMAT uses external beams for dose delivery and thus requires a full body contour for realistic treatment planning. Thus, we used the external contour from a second set of CT images with the whole body included
- By selecting appropriate planning objectives, the VMAT plan with two full arcs had improved HRCTV coverage, similar dose heterogeneity in the HDR plan, and acceptable OAR sparing
- Further studies with more patients and clinical trials are needed to confirm the clinical safety and efficacy of the VMAT modality

CONCLUSIONS

- Compared to the HDR interstitial plans, VMAT plans offer improved target coverage and similar dose inhomogeneity but slightly increased dose to the rectum
- Therefore, VMAT may be a feasible alternative for GYN cancer patients unwilling or unqualified for HDR interstitial brachytherapy

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