

Dosimetric Uncertainty In Simulation-Free Radiation Therapy: A Comparative Analysis of AP/PA, 3DCRT, and VMAT Planning Techniques for Palliative Spine Patients

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ABSTRACT

Simulation-free radiation therapy (SFRT) is an alternative workflow for palliative radiation therapy that utilizes existing diagnostic CT images for treatment planning, effectively reducing the time from consultation to treatment initiation. This study evaluated the dosimetric robustness of SFRT by comparing plans generated on diagnostic CT (dCT) and recalculated on planning CT (pCT) datasets. Nine patients were retrospectively analyzed using AP/PA, 3DCRT, and VMAT planning techniques with both 5 mm and 10 mm PTV margins. Differences in target coverage (CTV V100%, V95%, and V90%) and organ-at-risk metrics, including spinal cord maximum dose and lung V20, were assessed between dCT and pCT plans. For the 5 mm margin, mean CTV V100% differences were $0.6 \pm 1.0\%$, $-8.1 \pm 23.7\%$, and $-34.4 \pm 34.3\%$ for AP/PA, 3DCRT, and VMAT plans, respectively. For the 10 mm margin, corresponding differences were $0.4 \pm 0.7\%$, $-9.8 \pm 30.6\%$, and $-35.8 \pm 34.5\%$. In contrast, CTV V95% and V90% remained largely unchanged for AP/PA and 3DCRT plans, while VMAT demonstrated more modest reductions in V95% and minimal changes in V90%. For spinal cord maximum dose, absolute differences (pCT–dCT) were 39.3 ± 53.6 cGy, 33.0 ± 70.2 cGy, and -108.0 ± 127.1 cGy for AP/PA, 3DCRT, and VMAT plans with a 5 mm margin, and 71.2 ± 59.0 cGy, 55.3 ± 84.2 cGy, and -22.1 ± 152.6 cGy for the 10 mm margin. Mean lung V20 differences remained small, ranging from 0.5 to 3.8 percentage points across techniques and margin sizes. Overall, dosimetric differences between dCT and pCT plans were influenced more by treatment technique than PTV margin. AP/PA plans demonstrated the greatest robustness, 3DCRT showed intermediate performance, and VMAT exhibited the largest variability and reduction in target coverage.



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INTRODUCTION/AIMS

Simulation-free radiation therapy (SFRT): Eliminates the need for a dedicated CT simulation by using previously acquired diagnostic CT (dCT) images for treatment planning. Conventional kV CBCT can still be used for patient alignment during treatment.

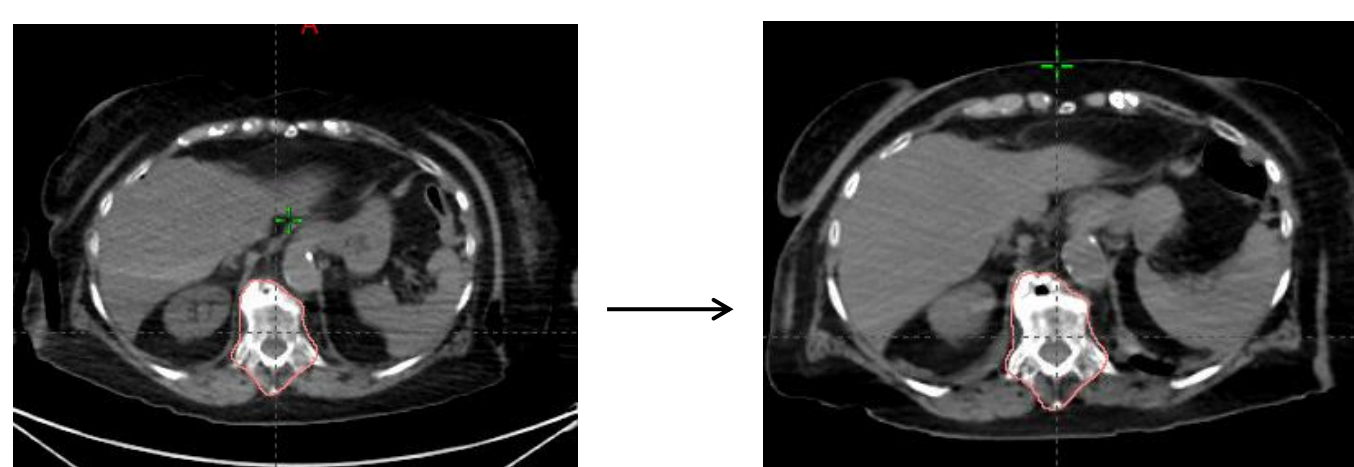
Key advantage of SFRT: Streamlines the treatment workflow, reducing the time between consultation and treatment for palliative patients.

Aim: While SFRT enables expedited treatment for palliative patients the impact of treatment planning technique on dosimetric uncertainty has not been previously reported and is the focus of this work.

METHOD

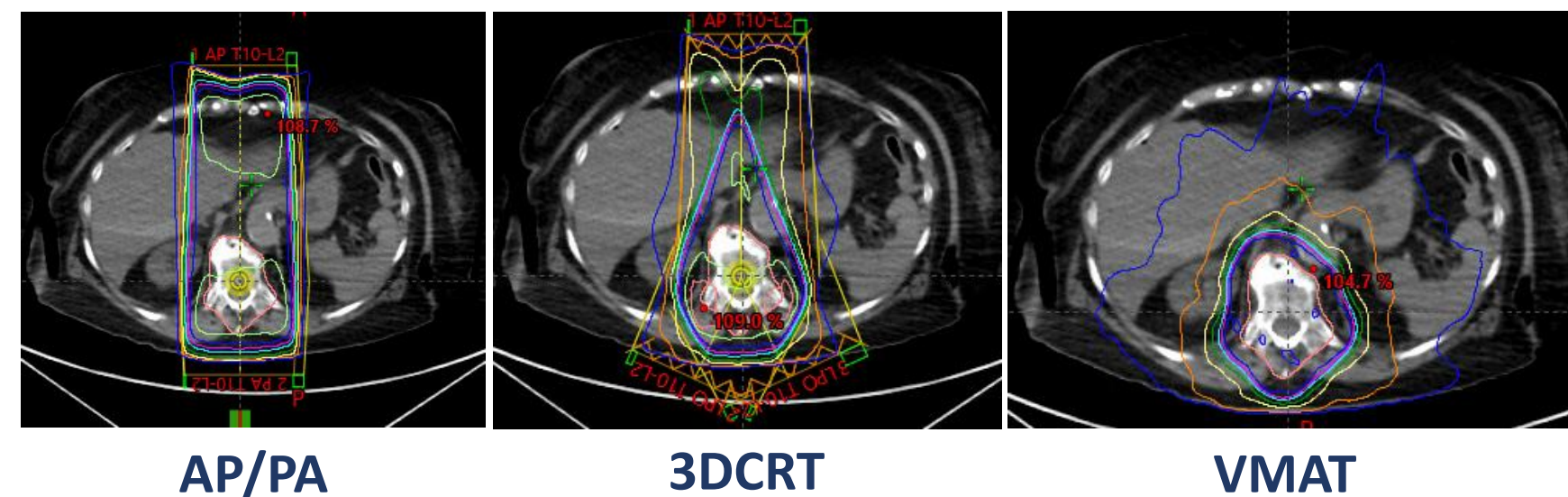
Nine previously treated spine cases were retrospectively selected. All plans were prescribed to 30Gy in 10 fractions. Three different planning techniques were used for each patient and two separate PTV margins were evaluated. Figure 1 displays the study design.

Image Registration & Contouring



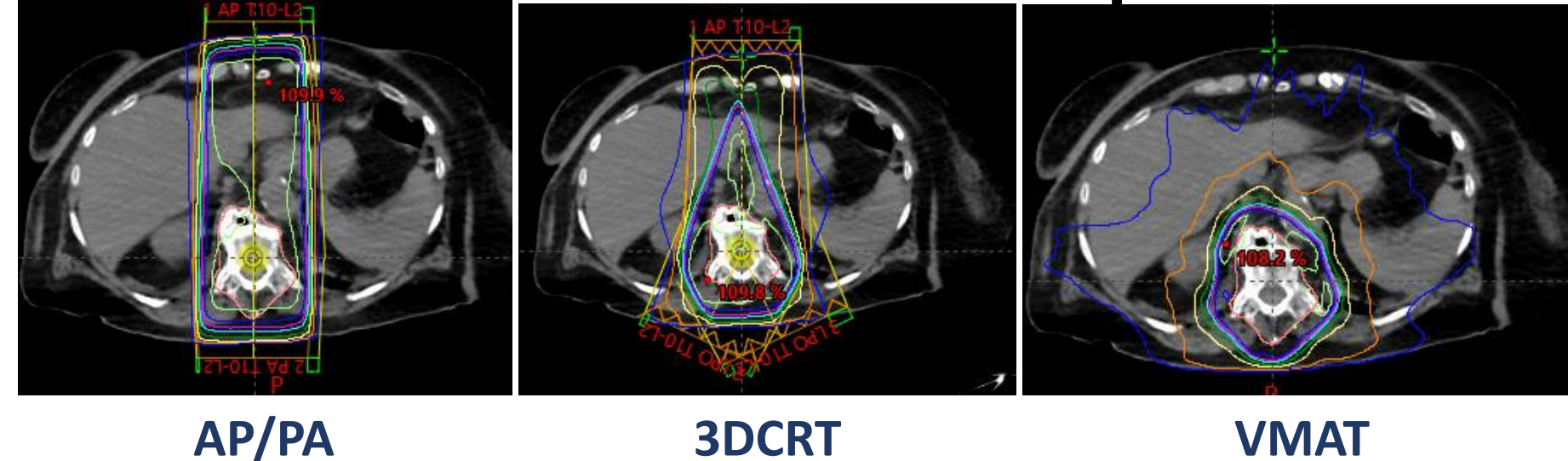
The CTV contour was propagated rigidly from the dCT to the pCT. Two PTV expansions created by adding a 5 mm and 10 mm margin to the CTV.

Planning on dCT (AP/PA, 3DCRT, VMAT)



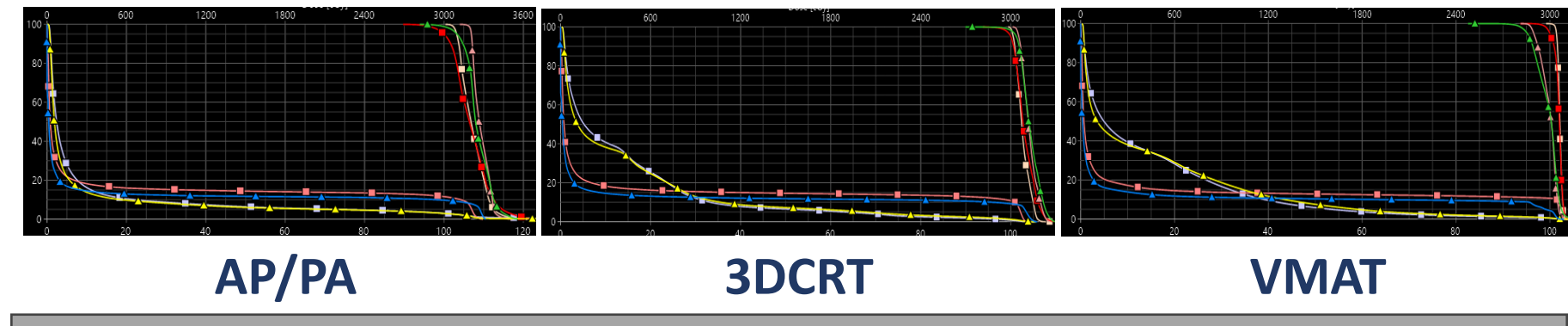
Three separate plans were created for each PTV margin. 1) an AP/PA plan, 2) a 3 field 3DCRT plan with field-in-field, 3) a VMAT plan with 2-3 arcs. All plans were normalized at PTVV100 = 95% Rx.

Plan Recalculation on pCT



All dCT plans were copied onto the rigidly registered pCT and recalculated with fixed MU from the dCT plan.

Dosimetric Comparison (pCT vs dCT)



Dosimetric comparison between the dCT and pCT plans were performed for the CTV D95 and V100, PTV D95 and V100, Lung V20, and spinal cord maximum dose (SCmax) for both PTV margins.

Figure 1. Workflow Overview

RESULTS



Figure 2. DVH comparison of the PTV (red), CTV (blue), lungs (yellow), and spinal cord (green) of one patient's AP/PA dCT (square) and pCT (triangle).



Figure 3. DVH comparison of the PTV (red), CTV (blue), lungs (yellow), and spinal cord (green) of one patient's 3DCRT dCT (square) and pCT (triangle).

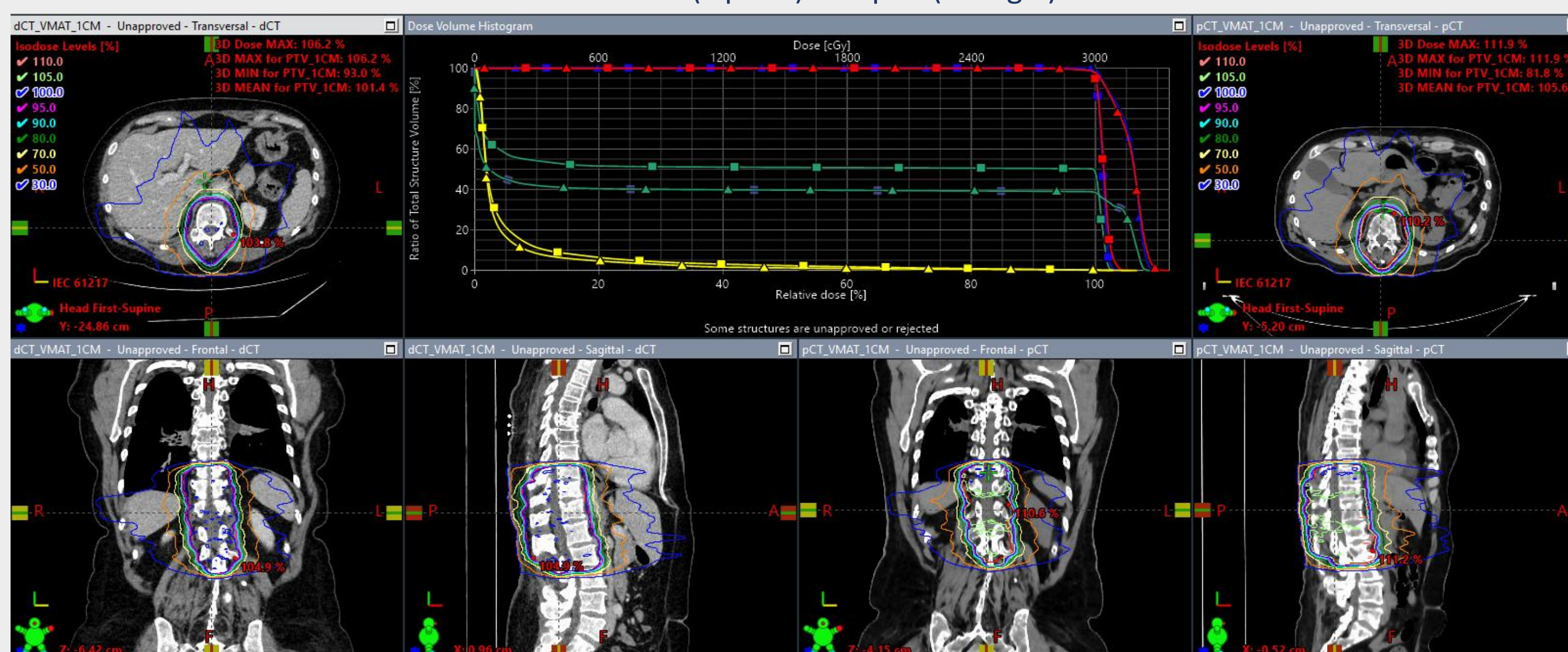


Figure 4. DVH comparison of the PTV (red), CTV (blue), lungs (yellow), and spinal cord (green) of one patient's VMAT dCT (square) and pCT (triangle).

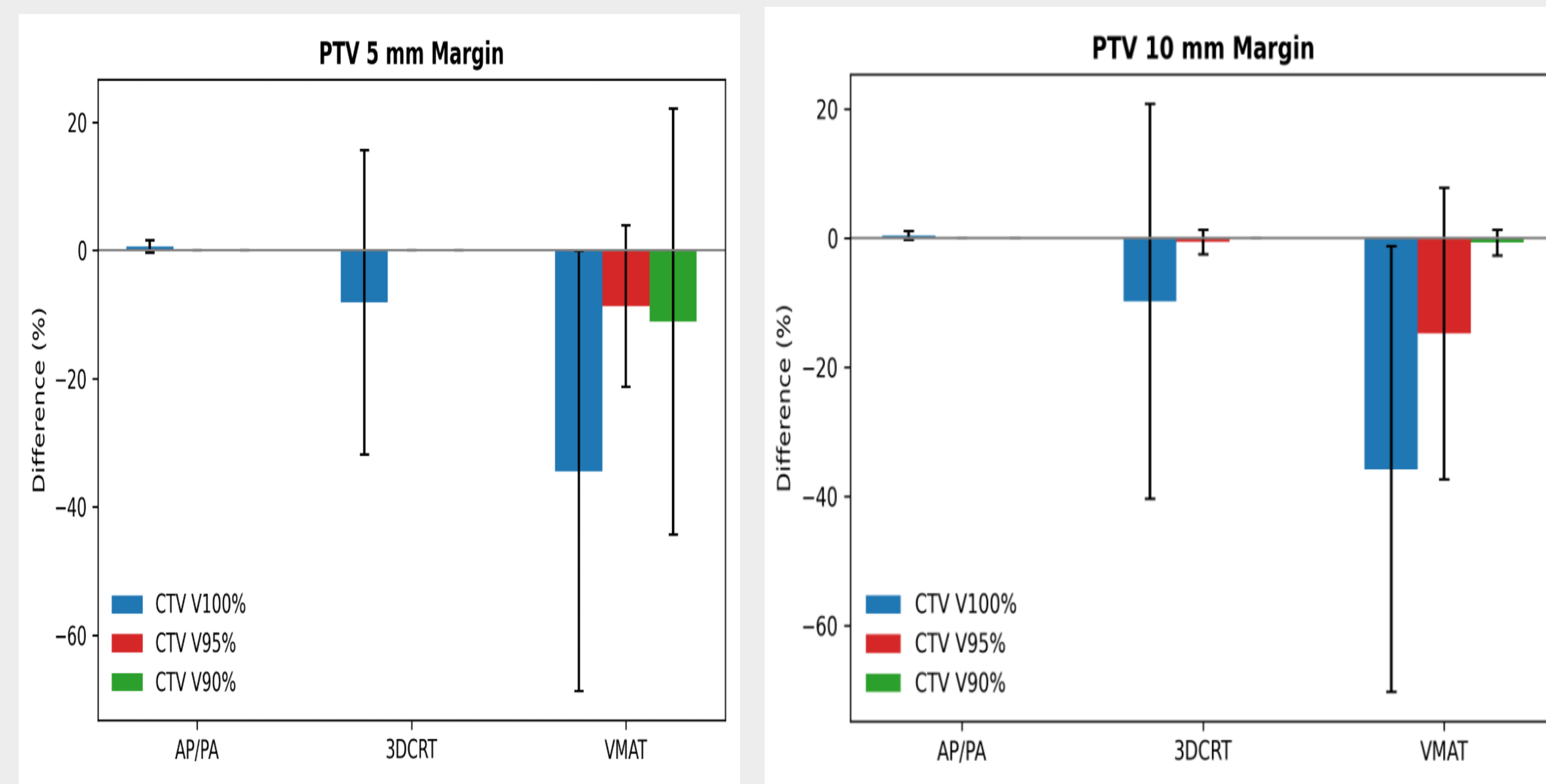


Figure 5. Percent difference between CTV V100%, CTV V95%, CTV V90% for all three techniques and both PTV margins.

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PTV 5 mm Margin

Technique	Mean Δ SCmax $\pm$ SD (cGy)
AP/PA	39.3 ± 53.6
3DCRT	33.0 ± 70.2
VMAT	-108.0 ± 127.1

Technique	Mean Δ Lung V20 $\pm$ SD (%)
AP/PA	1.8 ± 2.2
3DCRT	2.0 ± 2.0
VMAT	3.6 ± 6.0

PTV 10 mm Margin

Technique	Mean Δ SCmax $\pm$ SD (cGy)
AP/PA	71.2 ± 59.0
3DCRT	55.3 ± 84.2
VMAT	-22.1 ± 152.6

Technique	Mean Δ Lung V20 $\pm$ SD (%)
AP/PA	1.5 ± 1.7
3DCRT	0.5 ± 5.8
VMAT	3.8 ± 6.5

CONCLUSION

SFRT is an efficient alternative to conventional palliative workflows, but careful patient selection is required to balance expedited treatment with potential target coverage uncertainties.

Treatment technique had a greater impact on dosimetric differences than increasing the PTV margin from 5 mm to 10mm. AP/PA and 3DCRT demonstrated greater dosimetric robustness than VMAT when comparing dCT and pCT.

Variability in vertebral region among the nine patients likely contributed to the observed variability in the dosimetric results.