Rapid VMAT LATTICE Therapy Planning Using Deep Learning Predicted Synthetic CT from Diagnostic CT Scans

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ABSTRACT

OBJECTIVE
Volumetric Modulated Arc Therapy (VMAT) lattice therapy is utilized to treat bulky malignant tumors because of its biological effectiveness and local tumor control. This study aims to develop an expedited treatment process by utilizing synthetic CT (sCT) images generated through deep learning for VMAT lattice therapy.

METHODS
Two deep learning models, based on a 3D-UNet architecture, were trained to predict sCT for the thoracic and abdominal regions. VMAT lattice therapy plans were created on the 15 sCT cases and recalculated on the pCT. Clinical dose-volume histogram (DVH) metrics were used to assess dosimetric differences between the sCT and pCT, including D0.03cc for organ-at-risks (OARs), peak-to-valley dose ratio (PVDR), D10%, D50%, D90%, maximum, minimum and mean dose of gross tumor volume (GTV), and D50% of all spheres. Statistical significance between two CTs was determined using the Wilcoxon signed-rank test.

RESULTS
No statistically significant differences were found in the DVH metrics for the organs-at-risk in the thoracic and abdominal regions ($p > 0.05$). Among the GTV DVH metrics, only the minimum dose and D10% showed statistical significance, while PVDR, D50%, D90%, mean dose, and maximum dose did not. The mean absolute deviation between sCT and pCT was 0.32 Gy for GTV D10%, 0.18 Gy for D50%, 0.13 Gy for D90%, 0.41 Gy for PVDR, 0.43 Gy for the maximum dose, 0.23 Gy for the mean dose, 0.17 Gy for the minimum dose, and 0.40 Gy for all spheres' D50%.

CONCLUSIONS
The deep learning-generated sCT images were highly similar to pCT images and demonstrates the potential of using sCT to streamline treatment planning and accelerate VMAT lattice therapy delivery.

METHODS 1

- Two deep learning models, based on a 3D-UNet architecture, were trained to predict sCT for the thoracic and abdominal regions (**Figure 1**).

METHODS 2

- VMAT lattice therapy plans were created on the 15 sCT cases and recalculated on the pCT. Clinical dose-volume histogram (DVH) metrics were used to assess dosimetric differences.

FIGURE 1

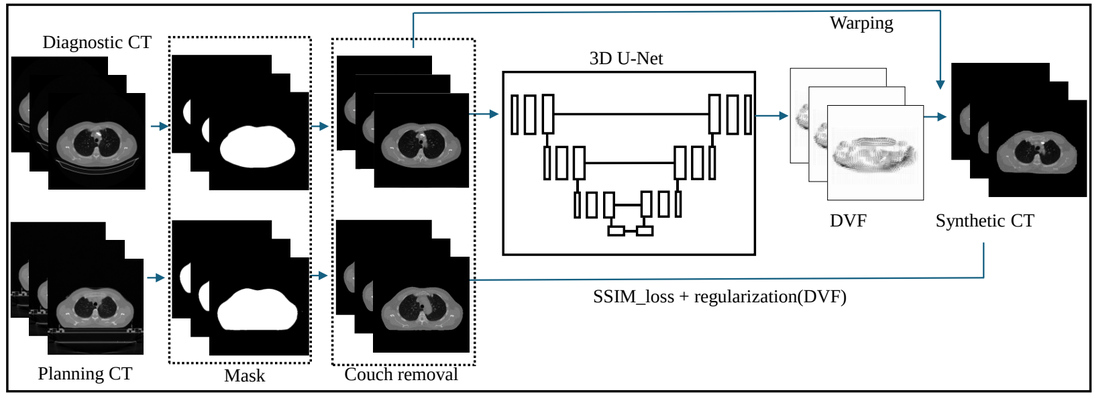

FIGURE 2

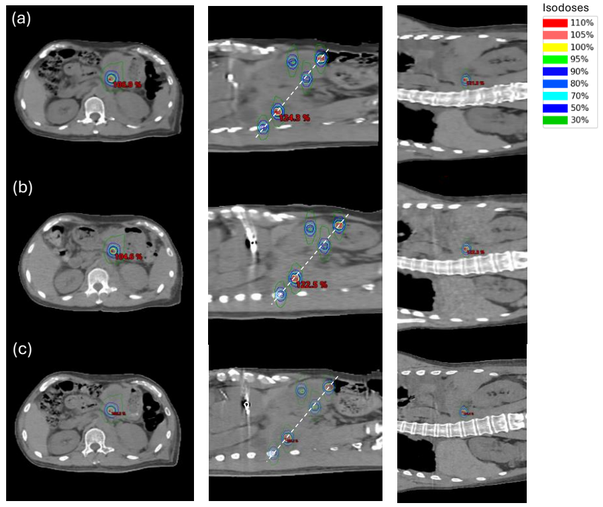

TABLE 1: DVH METRIC COMPARISON

	Thorax		Abdomen	
Metrics	dCT Vs. pCT	sCT Vs. pCT	dCT Vs. pCT	sCT Vs. pCT
MAE	140.69±36.67	38.93±14.79	109.48±22.53	73.60±22.90
SSIM	0.79±0.07	0.92±0.05	0.85±0.04	0.90±0.03
NCC	0.79±0.07	0.92±0.05	0.85±0.04	0.93±0.03
GMSD	0.35±0.02	0.32±0.02	0.34±0.01	0.32±0.01

RESULTS

- **Figure 2** shows dosimetric comparison between sCT (a), pCT (b) and dCT (c) from one patient.
- **Table 1** is quantitative comparison results for dCT Vs. pCT and sCT Vs. pCT.
- The final sCT prediction model demonstrated high image similarity to pCT, with a MAE and SSIM of 38.93±14.79 HU and 0.92±0.05 for the thoracic region, and 73.60±22.90 HU and 0.90±0.03 for the abdominal region, respectively.

CONCLUSIONS & FUTURE WORK

- High image similarity and adequate dose agreement is demonstrated between sCT and pCT.
- Our study is a proof-of-concept for using deep learning predicted sCT for a simulation-free treatment planning workflow for VMAT-based LRT.