Evaluation on Robustness of Volumetric Modulated Arc Therapy for Breast Cancer Treatment

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INTRODUCTION

For left-sided breast cancer treatments, deep inspiration breath hold (DIBH) is often implemented to reduce the dose to the heart, ipsilateral lungs, and left anterior descending artery (LAD) to minimize the side effects, especially cardiac toxicity and pneumonitis. However, not all patients can tolerate DIBH, making it desirable to have a free-breathing (FB) alternative. Volumetric modulated arc therapy (VMAT) has emerged as a potential solution to this issue as it can produce modulated segments to spare the critical organs at risk (OARs) while still providing adequate coverage to the target.

AIM

- Create clinical multifield 3DCRT and VMAT FB left breast plans on helical CT scans.
- Evaluate the effect of breathing motion on dosimetric parameters by recalculating these plans on 4DCT scans for the same patients.
- Compare these effects between 3DCRT and VMAT to determine if either type of plan is robust when treated FB.

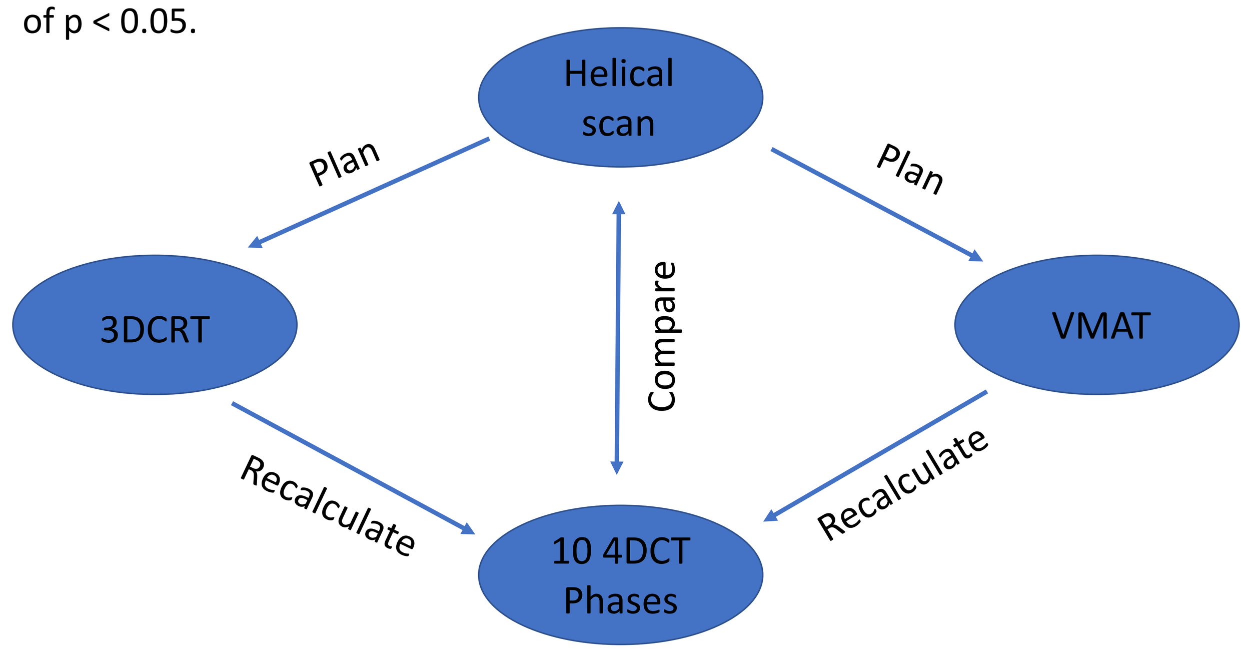
METHOD

On an IRB-approved protocol, retrospectively selected 6 female lung cancer patients treated with SBRT at MGH in Aug or Sept 2022 that had 4DCT and helical scans acquired on GE scanners. 4DCT scans were binned into 10 phases.

RayStation's deep learning Breast auto-contouring model was utilized to delineate targets and OARs on helical scans and all phases of the 4DCT, including: whole left breast, SCV nodes, IMNs, axillary level I-III nodes, heart, lungs, LAD, spinal cord, and contralateral breast. Manual refinement and stomach contouring were done by planners in MiM v7.0.5.

3DCRT and VMAT plans were generated for each patient on the helical scan following MGH standards utilizing RayStation v10A and Collapsed Cone v5.3 dose calculation algorithm for a Varian Truebeam linac (12 plans total). Plans were then copied and recalculated on each phase of the 4DCT (120 recalculations total).

Dose metrics for the targets and OARs were recorded and compared to the original plans for all 6 patients using a paired two-tail t-test with statistical significance of $p < 0.05$.



RESULTS

Target Coverage

For this cohort of 6 patients, there were no statistically significant ($p < 0.05$) changes observed in target coverage. For all targets except the supraclavicular nodes, 3DCRT was more impacted by breathing motion than VMAT, as shown by the higher mean absolute differences for 3DCRT in *Figure 1*. In general, reduced target coverage was observed on all phases of the 4DCT for both types of plan, with the average percentage loss shown in *Table 1*.

Target	Constraint	Mean Absolute Difference	
		3DCRT	VMAT
CTV_Total	D95 ≥ 4750 cGy	0.66%	0.51%
Breast_L	D95 ≥ 4750 cGy	0.7%	0.51%
LN_Ax_L1	D95 ≥ 4750 cGy	0.83%	0.1%
LN_Ax_L2	D95 ≥ 4750 cGy	3.53%	0.33%
LN_Ax_L3	D95 ≥ 4750 cGy	0.92%	0.61%
IMN	D92 ≥ 4500 cGy	3.08%	1.58%
Sclav	D95 ≥ 4750 cGy	0.74%	1.32%

Table 1. Mean absolute difference in target coverage, comparing planned dose on the helical scan for 3DCRT and VMAT to recalculated dose on 10 phases of 4DCT.

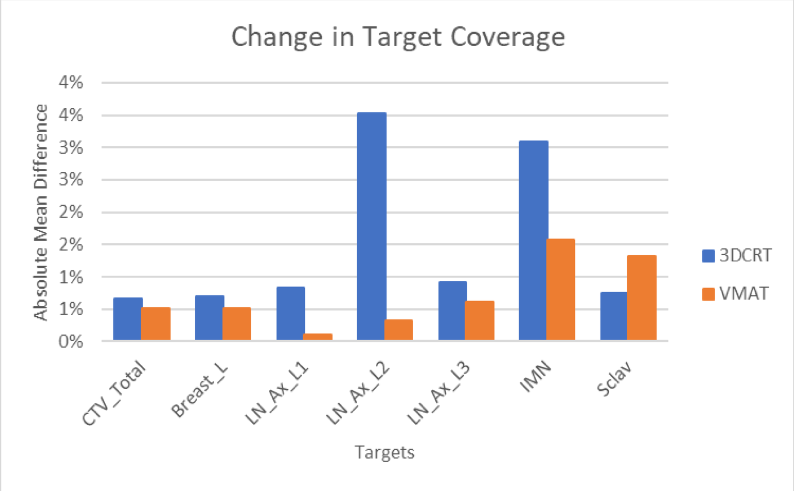


Figure 1. Comparison of the absolute difference in target coverage averaged over 6 patients, comparing planned dose on the helical scan for 3DCRT and VMAT to recalculated dose on 10 phases of 4DCT.

Normal Tissues Sparing

OARs	Constraint	Mean Absolute Difference	
		3DCRT	VMAT
A_LAD	Dmean < 800 cGy	11.2%	11.67%
A_LAD	Dmax < 1800 cGy	20.97%	6.86%
Heart	Dmean < 500 cGy	2.08%	1.64%
Lung_L	V20 < 30%	2.28%	1.47%
Lung_L	V5 < 65%	0.87%	0.77%
Spinal Cord	Dmax < 1200 cGy	12.23%	2.25%
Breast_R	V10 < 5%	33.58%	4.29%
Breast_R	Dmean < 700 cGy	3.22%	1.2%

Table 2. Mean absolute difference in OAR metrics, comparing planned dose on the helical scan for 3DCRT and VMAT to recalculated dose on 10 phases of 4DCT.

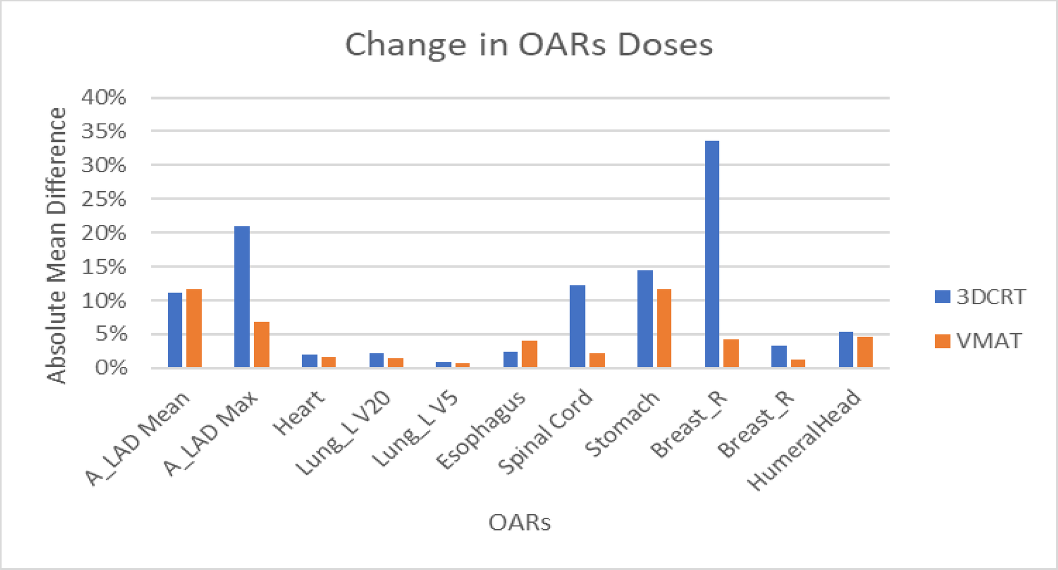


Figure 2. Comparison of the absolute difference in OAR metrics averaged over 6 patients, comparing planned dose on helical scan for 3DCRT and VMAT to recalculated dose on 10 phases of 4DCT.

Heart:

The only statistically significant change in OAR metrics was for the heart. The mean heart dose increased significantly for 3DCRT plans in 40%, 50%, and 60% (exhale) phases, while VMAT plans showed a significant decrease in mean heart dose for the 0% (inhale) phase and significant increase only for the 40% phase, as shown in *Figures 3* and *4* and *Table 3*.

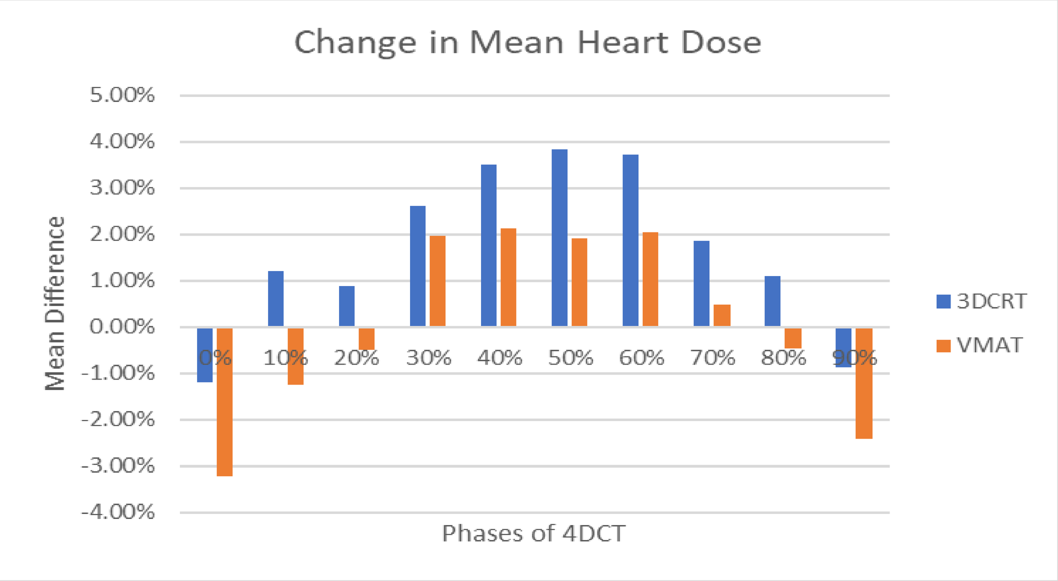


Figure 3. Comparison of the difference in heart mean dose averaged over 6 patients for each phase of the 4DCT, comparing planned dose on the helical scan for 3DCRT and VMAT.

		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%
Heart	3DCRT	-1.20%	1.20%	0.88%	2.63%	3.50%	3.83%	3.72%	1.86%	1.10%	-0.88%
	VMAT	-3.22%	-1.24%	-0.49%	1.98%	2.12%	1.91%	2.05%	0.49%	-0.46%	-2.40%

Table 3. Difference in mean heart dose averaged over 6 patients, comparing planned dose on helical scan for 3DCRT and VMAT to recalculated dose on 10 phases of 4DCT. Statistically significant changes ($p < 0.05$) are highlighted in yellow. Negative values indicate a decrease while positive values indicate an increase in mean heart dose.

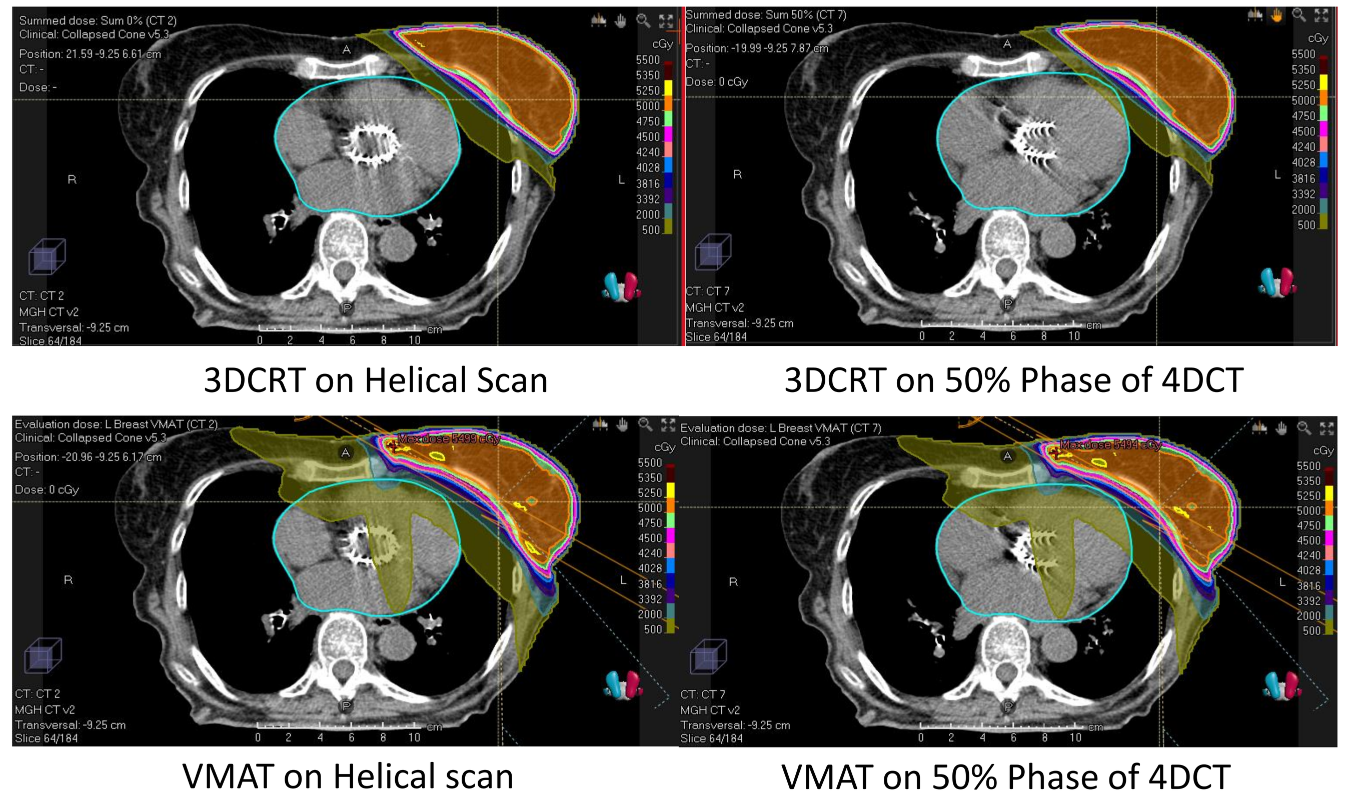


Figure 4. Isodose distributions of 3DCRT and VMAT plans showing the difference in low dose to heart between planned dose on helical scan and recalculated dose on the 50% phase of 4DCT for one representative patient case.

Summary:

Both 3DCRT and VMAT plans showed differences from the planned dose on a helical scan when recalculated on the 10 phases of a 4DCT. With 6 patients, changes other than for heart mean dose were not statistically significant, but trends were compared for 3DCRT versus VMAT. Lower target coverage was observed for all phases of 4DCT for both types of plan, but the change was larger for 3DCRT except for supraclavicular nodes. Most of the OAR metrics showed larger changes for 3DCRT than VMAT plans; the lung and heart metrics showed a trend of decreased dose for inhale phases and increased dose for exhale phases.

CONCLUSIONS

While the sample size of 6 patients was too small for most results to reach statistical significance, the overall trends showed that ignoring breathing motion in FB planning could result in lower target coverage and higher heart dose than predicted. The findings of this study agree with a previous study that VMAT FB plans deliver higher mean dose to the heart than 3DCRT FB plans,[1] but this study found the change in mean heart dose with breathing motion is smaller in VMAT than 3DCRT.

VMAT plans appeared to be more robust to breathing motion than 3DCRT as most target and OAR metrics saw less change across breathing phases for VMAT. One limitation of this study is that it used SBRT lung patients who were not scanned on a breast board; anatomic changes with breathing motion may vary for patients on a breast board. Further studies with a larger patient cohort using patients on a breast board are needed to conclusively evaluate plan robustness with breathing motion.

REFERENCES

1. **Jensen, C. A., Funderud, M., & Lervåg, C.** (2021). Free breathing VMAT versus deep inspiration breath-hold 3D conformal radiation therapy for early stage left-sided breast cancer. Journal of applied clinical medical physics, 22(4), 44–51. https://doi.org/10.1002/acm2.13208

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