Quantifying the dosimetric impact of target margins in the oligometastatic setting

Jessica Strang, B.S., RT(T), Gemma A. Davies Ph.D., Carri Glide-Hurst Ph.D., Alyx Alfson M.S. CMD RT(T), Kristen Vu M.S. CMD RT(T)

Introduction

- With recent advancements in cancer treatment therapies , patients are living longer with oligometastatic disease[1]
- Treating multiple intrathoracic lesions using a single isocenter[1,2] makes treatment time more manageable for patients
- However, treating multiple targets using a single isocenter may result in geometric miss and resultant suboptimal coverage, which may adversely impact patient outcomes[3,4]
- While increasing the planning target volume (PTV) size reduces the risk of geometric miss, it also increases the volume of normal lung tissue irradiated
- This study evaluated the interplay between increased dose to normal lung tissue and other organs at risk (OARs) as the PTV margin is increased for multiple intrathoracic gross tumor volumes (GTVs) treated with a single isocenter to support single isocenter radiation therapy in the oligometastatic setting

Methods

- 15 patients with 2-3 oligometastatic thoracic lesions (total GTVs = 37)
- Average GTV volume 0.57 ± 0.50 cc (range: 0.08 cc - 2.27 cc)
- Dosimetric endpoints followed RTOG 0915 as outlined in Table 1:

Metric for Lungs-GTV	Goal/Constraint
V20Gy	< 10-15%
Mean Lung Dose (MLD)	< 20 Gy
V1000cc	< 7.4 Gy
V1500cc	< 7 Gy

Table 1: RTOG 0915 lung constraints

Breath-hold gated CT simulation scans were acquired for 15 patients with multiple intrathoracic lesions using Varian RPM

GTVs contoured by MD and were given three levels of PTV isotropic expansions; 5 mm, 7 mm, and 9 mm

Plans generated for each margin level prescribed to 50 Gy in 5 fractions

Plans evaluated for conformity and meeting endpoints for normal lung (defined as total lung volume with GTVs subtracted), V20, V5, chest wall etc

Difference in lung dose, OARs, and conformity evaluated for statistical significance between three margin levels for each patient

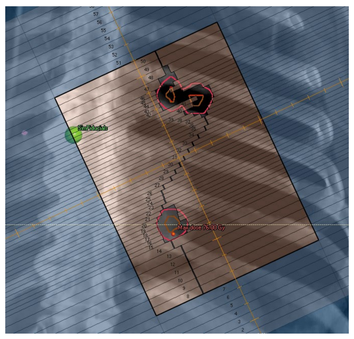

Figure 1: Multiple targets with centrally placed isocenter

Function	Constraint	Dose	ROI	Description	Robust	Weight	Value
Physical composite objective							0.0031
Min dose		Plan	GTV1	Min dose 61.50 Gy		0.10	1.7114E-6
Min dose		Plan	GTV2	Min dose 61.50 Gy		0.10	0.0000
Min dose		Plan	GTV3	Min dose 61.50 Gy		0.10	0.0000
Min dose		Plan	OTV1_5000_5mm	Min dose 51.25 Gy		5.00	1.5048E-4
Min dose		Plan	OTV2_5000_5mm	Min dose 51.25 Gy		5.00	1.4394E-4
Min dose		Plan	OTV3_5000_5mm	Min dose 51.25 Gy		5.00	7.2082E-5
Max dose		Plan	OTV1_5000_5mm	Max dose 72.00 Gy		0.10	0.0000
Max dose		Plan	OTV2_5000_5mm	Max dose 72.00 Gy		0.10	1.4818E-6
Max dose		Plan	OTV3_5000_5mm	Max dose 72.00 Gy		0.10	2.1263E-6
Max dose		Plan	Ring_HD_5mm	Max dose 1.00 Gy		0.00	0.0026
Max dose		Plan	Normal_2cm_5mm	Max dose 15.00 Gy		1.00	7.9286E-5

Figure 2: Standard objectives utilized in plan studies

Results

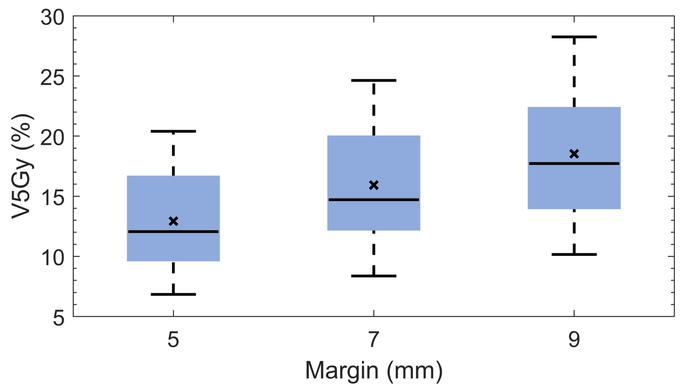

Figure 3: Boxplot of normal lung V5Gy (%)

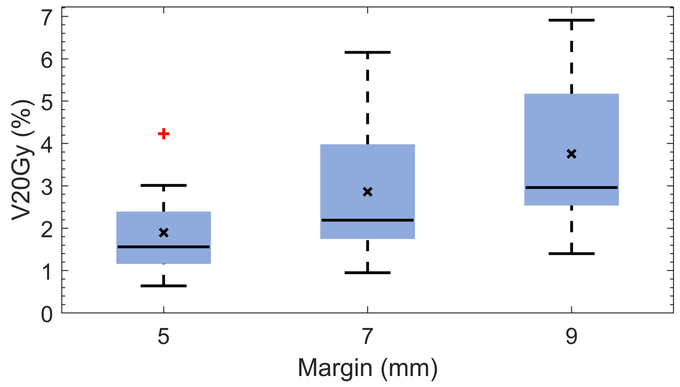

Figure 4: Boxplot of normal lung V20Gy (%)

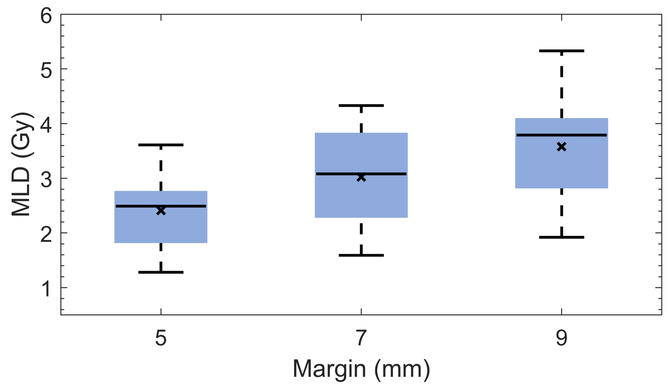

Figure 5: Boxplot of mean lung dose (Gy)

Margin (mm)	Mean ± Std Dev (Gy)	Confidence Interval
5	45.6 ± 9.4	40.4 - 50.8
7	47.7 ± 7.5	43.5 - 51.8
9	49.4 ± 6.3	45.9 - 52.9

Table 2: Population average maximum esophageal dose (Gy)

Margin (mm)	Mean ± Std Dev (Gy)	Confidence Interval
5	8.2 ± 2.9	6.9 - 9.9
7	9.1 ± 3.6	7.1 – 11.1
9	10.6 ± 4.0	8.3 – 12.8

Table 3: Population average maximum chest wall dose (Gy)

Discussion

Population average results with margin increase from 5 mm – 7 mm:	Population average results with margin increase from 5 mm – 9 mm:
↑V5 from 12.9% to 15.9%	↑V5 from 12.9% to 18.5%
↑V20 from 1.9% to 2.9%	↑V20 from 1.9% to 3.8%
↑MLD 0.6 Gy	↑MLD 1.2 Gy
↑Max chest wall dose by 2.1 Gy	↑Max chest wall dose by 3.9 Gy
↑Spinal cord max dose by 0.9 Gy	↑Spinal cord max dose by 2.4 Gy

- All dosimetric results across different margin expansions were statistically significant using a one-way ANOVA repeated measures test.
- All plans met the clinical goals outlined by the supervising institution. However, there is a likelihood these patients may need more radiation therapy in the future, so the principle of ALARA may be particularly beneficial.
- As margins increased from 5 mm to 7 mm to 9 mm, the average conformity index also increased from 0.81 to 0.85 to 0.87, respectively. Further investigation is warranted to explain this finding.
- An outlier patient was identified in Figure 4 who had all three targets located in the same axial plane resulting in increased cross-talk. This suggests that combining targets may be more challenging when spatial distance is limited between isolated metastases.
- Limitations of this study include a limited sample size, the limit to two to three intrathoracic lesions, and implementing uniform, isotropic expansions.

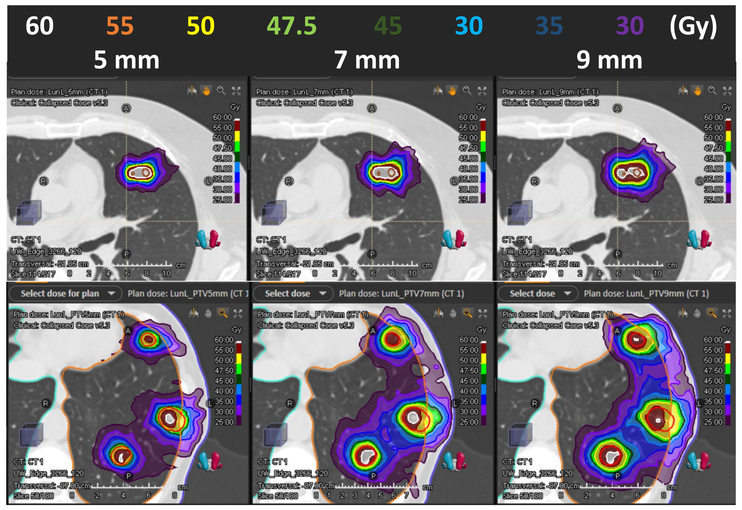

Figure 7 : Axial slices comparing isodose lines for a typical patient (top) and for the outlier patient (bottom) described in Figure 4.

Conclusions

This study quantified the dosimetric impact of increasing PTV margins to reduce potential geometric misses during radiation delivery. For the 15 patients considered, the PTV margin could be safely increased to 9 mm without compromising normal tissue constraints. This provides greater assurance that the GTVs will be contained within the PTVs during the several breath-holds required for gated treatments when multiple lesions are being treated simultaneously with one isocenter. Future studies could apply margins to on-board images to determine setup reproducibility and further validate the final margin expansion to yield safe and effective radiation therapy.

References

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