A Comparison Between Single-Isocenter and Multi-Isocenter Plan Quality for Multi-Target Abdominal Radiation Treatments

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Introduction

Open clinical trials studying treatment options for patients with oligometastatic disease have led to an increase in abdominal multi-target radiation treatments at MD Anderson Cancer Center.[1,2] While single-isocenter plans are faster to deliver and easier on patients than multi-isocenter plans, they have limitations and may not provide adequate coverage of the targets.

Multi-isocenter treatment plans may be preferable for patients with greater spatial separation between targets, proximity to critical organs at risk (OARs), or substantial motion in the tissues being irradiated. However, they require longer treatment times and may increase the dose to normal tissues due to overlapping doses.[3]

This study aims to determine whether single-isocenter or multi-isocenter treatment plans are more beneficial for oligometastatic disease by creating multiple plans per patient and comparing overlapping dose, dose to OARs, and target coverage.

Methods

Patients in the EXPAND (NCT06593431) or EXTEND-OP (NCT06367972) clinical trial with at least two abdominal targets were considered for this study. Selection was based on the distance between targets, defined as the distance from the inferior portion of one target to the superior portion of the adjacent target, being within 5 cm.

Our sample size included twelve patients who were replanned with SBRT using VMAT and optimized based on each patient's original prescription and clinical goals. A single-isocenter and composite multi-isocenter plan were created for each patient. All plans were treated to 4 or 5 fractions to all targets.

Single-isocenter plans were optimized using a single beam set, with one treatment isocenter centrally located relative to all planning target volumes (PTVs). Multi-isocenter plans used dedicated treatment isocenters placed centrally within each PTV and were optimized using RayStation's co-optimization function. Cases with three targets required two targets to be co-optimized, with the third being optimized independently. Dose received from other isocenters was reduced as much as possible.

Dose metrics used to evaluate and compare plans are shown by Table 1. GTV and PTV dose metrics were calculated by averaging the values across all targets within each plan.

Table 1. Dose metrics used to evaluate and compare plans.

Volume	Dose Metric Evaluated
GTV	D95%, D99%, D100%, V100%
PTV	D95%, D99%, D100%, V100%
Esophagus	Dmax, D1cc
Stomach	Dmax, D1cc
Duodenum	Dmax, D1cc
Small Bowel	Dmax, D1cc
Large Bowel	Dmax, D1cc
Heart	Dmax, D1cc, Dmean
Left Kidney	Dmax, D1cc
Right Kidney	Dmax, D1cc
Spinal Cord	Dmax, D1cc
Liver-GTV	Dmean, V<15Gy, V12Gy
Spleen	Dmean

Results and Discussion

Both single- and multi-isocenter approaches produced clinically acceptable treatment plans for patients with oligometastatic abdominal disease, achieving comparable target coverage and meeting established clinical goals.

Most differences between the evaluated dose metrics were not statistically significant, except those observed by the heart, duodenum, right kidney, and PTV D95%. Variability in organ at risk (OAR) sparing and target coverage between the plans was observed on a per-target basis, with some cases favoring one approach over the other.

Overall, multi-isocenter plans demonstrated modest improvements in target coverage and OAR sparing. However, these benefits were accompanied by increased planning complexity and time. In contrast, single-isocenter plans offered advantages in workflow efficiency, including reduced setup uncertainty, and shorter treatment times.

Figure 1. Box plot and p-value statistics comparing target coverage metrics between single-isocenter and multi-isocenter plans. A discovery indicates a statistical significance ($p < 0.05$) and is noted by *. Non-significant differences are noted by "ns".

Target Coverage	Discovery?	P value
GTVs V100% avg	No	0.067
GTVs D95% avg	No	0.30
GTVs D99% avg	No	0.62
GTVs D100% avg	No	0.68
PTVs V100% avg	No	0.077
PTVs D95% avg	Yes	0.034
PTVs D99% avg	No	0.11
PTVs D100% avg	No	0.077

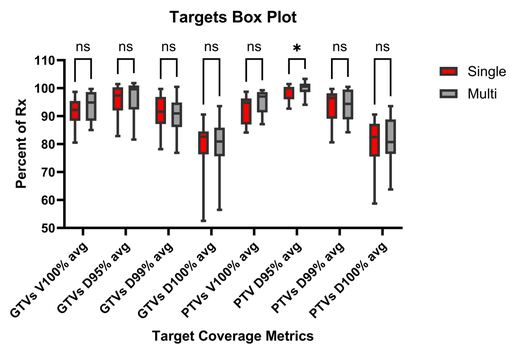


Figure 2. Box plot and p-value statistics comparing dose metrics for OARs between single-isocenter and multi-isocenter plans. A discovery indicates a statistical significance ($p < 0.05$) and is noted by *. Non-significant differences are noted by "ns".

OAR Doses	Discovery?	P value
Esophagus Dmax	No	0.15
Esophagus D1cc	No	0.18
Stomach Dmax	No	0.10
Stomach D1cc	No	0.75
Duodenum Dmax	Yes	0.00048
Duodenum D1cc	Yes	0.0034
Small Bowel Dmax	No	0.57
Small Bowel D1cc	No	0.79
Large Bowel Dmax	No	0.57
Large Bowel D1cc	No	0.85
Heart Dmax	Yes	0.027
Heart D1cc	Yes	0.012
Heart Mean Dose	Yes	0.00097
L Kidney Mean Dose	No	0.34
R Kidney Mean Dose	No	0.17
Spinal Cord Dmax	No	0.57
Spinal Cord D1cc	No	0.68
Spleen Mean Dose	No	0.85
Liver-GTV Mean Dose	No	0.07

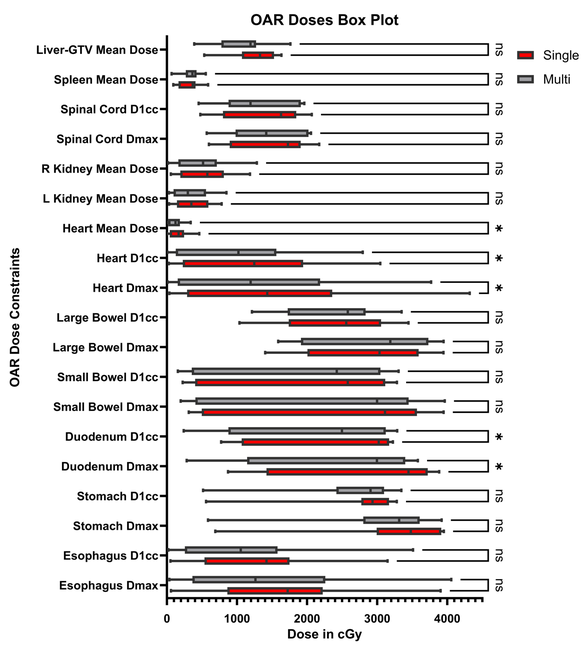
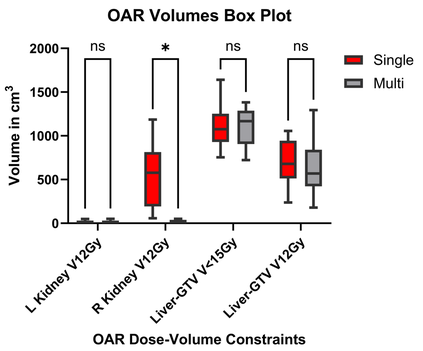


Figure 3. Box plot and p-value statistics comparing the volume receiving specified dose for OARs between single- and multi-isocenter plans. A discovery indicates a statistical significance ($p < 0.05$) and is noted by *. Non-significant differences are noted by "ns".

OAR Volume Constraints	Discovery?	P value
L Kidney V12Gy	No	0.74
R Kidney V12Gy	Yes	0.00048
Liver-GTV V<15Gy	No	0.97
Liver-GTV V12Gy	No	0.38



Conclusion

The observed statistically significant differences in dose to OARs highlight the importance of individualized treatment planning. Our findings suggest that neither approach is universally superior.

Instead, the optimal strategy should be determined based on patient-specific anatomy, target geometry, clinical priorities, and the ability to replicate dose distribution during treatment. Careful evaluation of these factors is essential to balance plan quality, efficiency, and potential toxicity in clinical decision-making.

Limitations

This study only evaluated the planned dose, not delivered dose. With multi-target abdominal planning, the delivered dose may vary from the planned dose due to differences in anatomy or daily treatment setup.

Planner-dependent variability remains a significant challenge in evaluating multi-target abdominal SBRT plans, as differences in experience and technique can influence plan quality and optimization outcomes. Additionally, the small sample size of twelve cases, comprising of ten patients with two lesions and two patients with three lesions, limits the generalizability of these findings.

Future studies should incorporate a larger sample size, a wider range of anatomical variability (including differences in organ size and inter-target distance), evaluation of delivered dose, and an opportunity to assess plan quality across different treatment planning systems to better characterized scenarios in which one approach may be preferred.

References

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