O-Ring Platform Automated Planning for Lattice Stereotactic Body Radiotherapy (SBRT) Across Diverse Anatomical Sites: Strengths and Limitations

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Abstract

Purpose: The Intelligent Optimization Engine (IOE) on Varian Ethos has demonstrated efficient Lattice SBRT planning for lung tumors. However, generalizability of IOE performance across diverse anatomical sites and tumor sizes remains unexplored. This study evaluates IOE-generated Lattice plans across multiple anatomical regions to establish the scope and limitations of automated planning compared to clinically delivered C-arm linac plans.

Methods: Eleven previously treated tumors spanning thoracic, abdominal, pelvic, and extremity sites (volume: 2039.6 ± 2043.6 cm³) were retrospectively replanned using standardized RT Intent with IOE on Ethos platform. Original plans were created in Eclipse on C-arm linacs with Millennium-120 and HD-120 MLCs. Dosimetric evaluation followed LITE SABR M1 protocol criteria: PTV_Peak mean dose, PTV_Avoid mean dose, dose ratio (DR), conformity index (CI), PTV V95%, DR_1.5cm, and monitor units (MUs).

Results: For targets ≤24 cm in superior-inferior dimension, IOE produced plans meeting LITE SABR M1 metrics across all anatomical sites. PTV_Peak mean dose exceeded 95% with improved dose conformality (CI: 1.0) compared to Eclipse ($p = 0.04$). Targets exceeding 28 cm required multi-isocenter planning, which failed to achieve characteristic lattice dose distributions. Plan quality degraded for large volumes (PTV>3500 cm³), with PTV_Peak mean dose and PTV V95% falling below 90% and DR below 3. IOE demonstrated reduced MUs in 63% of cases (two-tailed t-test, $p = 0.01$). Four full arcs with widely spaced collimator angles consistently achieved comparable plan quality, while C-arm linacs with HD-120 MLCs demonstrated an advantage in cases involving non-coplanar beam geometries.

Conclusions: Ethos IOE generates clinically acceptable Lattice SBRT plans across diverse anatomical sites for targets under 24 cm, reducing MUs and planning complexity. It provides a robust, site-independent automated planning solution for appropriately sized targets, with some performance limitations in large volumes.

Introduction

- Lattice SBRT is an advanced spatially fractionated technique that delivers high-dose "grid" radiation to focal hotspots (PTV_Peak) within a large tumor volume while maintaining lower doses in the intervening areas including PTV_Avoid, effectively treating bulky masses while sparing adjacent healthy tissue
- As the target volume increases and the number of PTV_Peak spheres grows, Lattice SBRT plan quality metrics, as outlined in LITE SABR M1 trial,[1] become highly challenging to achieve, often requiring experienced planners to spend hours or even days optimizing the dose distributions
- The Intelligent Optimization Engine (IOE) on Ethos platform was reported to produce complex Lattice plans consistently and efficiently for NSCLC lung tumors (mean ± SD of PTV volume approximately 860 ± 350 cm³) [2]
- This study evaluated the strengths and limitations of Ethos across various tumor sites (thoracic, abdominal, pelvic, and extremity tumors) and a wide range of tumor sizes (2039.6 ± 2043.6 cm³)

Methods

- Eleven previously treated tumors planned in Eclipse TPS (v16.1) on C-arm linear accelerators (linacs) with Millennium120 or HD120 Multi-Leaf Collimators (MLCs) were selected
- Anatomical sites included thorax, abdomen, pelvis, and extremity
- Prescription: 20 Gy to PTV and PTV_Avoid, 66.7 Gy to PTV_Peak, in 5 fractions
- All cases were imported into Ethos Treatment Management (v3.0) and replanned using a standardized RT Intent with IOE (v2)
- Dosimetric evaluation followed LITE SABR M1 protocol criteria. Metrics reported in this study include:
  - PTV_Peak_{mean}: mean dose in PTV_Peak
  - PTV_Avoid_{mean}: mean dose in PTV_Avoid
  - DR: dose ratio $PTV\_Peak_{mean}/PTV\_Avoid_{mean}$
  - PTV CI: PTV Conformity Index = $V_{100\%}/V_{PTV}$
  - $PTV_{V95\%}$: PTV covered by 95% prescription isodose line
  - DR_1.5cm: dose ratio within 1.5cm of PTV_Peak
  - Total monitor units (MUs)

Results and Discussions

Table 1: Dosimetric evaluation metrics for the cases involving tumors up to 24cm in length. Data are presented as Mean ± SD (min-max)

Evaluation metric	LITE SABR M1	Eclipse (C-arm linacs)	Ethos
# of spheres	9.0 ± 8.7 (1.0-34.0)	16.0 ± 10.1 (6.0-40.0)	16.0 ± 10.1 (6.0-40.0)
PTV_Peak_{mean} (Gy)	71.8 ± 0.9 (68.9-72.8)	70.0 ± 1.3 (69.1-72.6)	72.1 ± 4.0 (63.6-76.9)
PTV_Avoid_{mean} (Gy)	21.0 ± 1.0 (19.4-23.2)	22.2 ± 1.0 (20.7-23.9)	21.7 ± 0.5 (20.6-22.1)
DR	3.5 ± 0.2 (3.0-3.7)	3.2 ± 0.1 (2.9-3.4)	3.3 ± 0.3 (2.9-3.7)
PTV CI	1.4 ± 0.2 (0.9-1.8)	1.1 ± 0.1 (1.0-1.4)	1.0 ± 0.1 (0.9-1.2)
$PTV_{V95\%}$ (%)	99.9 ± 1.3 (94.8-100)	98.8 ± 0.5 (98.3-99.7)	94.8 ± 3.3 (87.2-98.9)
DR_1.5cm	3.1 ± 0.5 (2.4-4.6)	3.2 ± 0.3 (2.8-3.8)	3.4 ± 0.4 (2.6-3.7)

- As shown in Table 1, Ethos IOE generated plans of comparable quality to LITE SABR M1 and our clinical Eclipse plans for tumors up to 24 cm across all anatomical sites
- PTV_Peak_{mean} in Ethos plans all exceeded 95%
- While Ethos maintained PTV_Avoid_{mean} more consistently than Eclipse plans with a lower standard deviation and tighter range, the difference was not statistically significant ($p = 0.14$)
- $PTV_{V95\%}$ was lower overall in Ethos plans ($p < 0.01$), likely because Ethos generated more conformal plans as evidenced by the PTV CI:
  - Ethos produced a mean CI of 1.0 (range: 0.9–1.2), while Eclipse and LITE SABR M1 had higher CI overall ($p = 0.04$)
- Targets exceeding 28 cm required multi-isocenter planning, which failed to achieve characteristic lattice dose distributions, likely due to the underlying auto-feathering requirement
- For Patient #3 in Figure 1 (PTV length: 24 cm, volume: 3693 cm³), the Ethos plan MU was 5160 lower than Eclipse while maintaining acceptable plan quality. However, plan quality was degraded for Patient #7 (31 cm, 7291 cm³) and #10 (26 cm, 5258 cm³):
  - For Patient #7, PTV_Peak_{mean}, PTVV95% and DR were 53.7 Gy, 86.1%, and 2.1, respectively; for Patient #10, these values were 59.9 Gy, 88.8%, and 2.5.
- Regarding beam geometry, four full arcs with widely spaced collimator angles consistently achieved comparable plan quality
- C-arm linacs demonstrated an advantage in cases larger than 25 cm or involving non-coplanar beam geometries

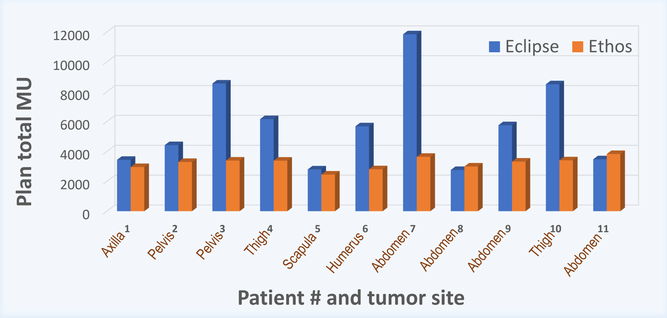

Figure 1. MU comparison of all 11 cases

- As shown in Figure 1, IOE demonstrated reduced MUs in 63% of cases (two-tailed t-test, $p = 0.01$) and less MU variation across all tumor sites and sizes

Conclusions

- Ethos IOE generates clinically acceptable Lattice SBRT plans across diverse anatomical sites for targets under 24 cm, reducing MUs and planning complexity.
- It provides a robust, site-independent automated planning solution for appropriately sized targets, with some performance limitations in large volumes.

References

1. Kavanaugh, J.A., et al., *LITE SABR M1: Planning design and dosimetric endpoints for a phase I trial of lattice SBRT*. Radiother Oncol, 2022. **167**: p. 172-178.
2. Sait, A.A., et al., *Evaluating the Ethos automated planning system for spatially fractionated radiotherapy*. J Appl Clin Med Phys, 2025. **26**(10): p. e70306.