Evaluating Planning Strategies for Isotoxic Liver ART

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Introduction

- Liver cancer is a malignant cancer that has poor prognosis. Due to the proximity of sensitive organs, it can be challenging to treat.
- Adaptive Radiotherapy (ART) considers the changes of a patients' anatomy by using AI automatic contouring and optimization based on cone-beam computed tomography (CBCT) imaging to generate a plan on-line.
- The Varian Ethos therapy system can automatically generate plans for adaptive treatments using an intelligent optimization engine (IOE). It is also capable of auto-segmentation as shown in Fig.1.
- In addition to the generated IOE structures, a planning risk volume (PRV) is often added around organs during planning for Isotoxic treatments.

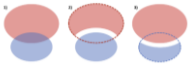


Fig 1. Target (red) vs. OAR (blue). IOE automatically crops overlapping volumes based on user priority.

Purpose

- To streamline workflow processes for isotoxic ART
- Assess the effectiveness of the IOE for generating Isotoxic plans
- Determine the effect of user-defined structures on plan quality in isotoxic ART treatments

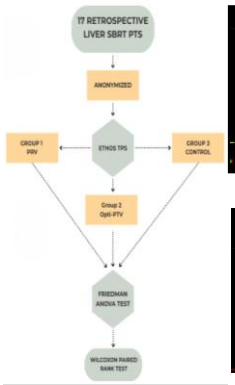
Methods

Seventeen retrospective liver ART patients were replanned using three techniques:

1. PRV-based (placed around stomach, bowel and duodenum)
2. Opti-PTV (PTV subtracted from the organs at risk (OARs))
3. Automated IOE (no manual edits).

- All plans were evaluated using target coverage (V100%), Conformity Index (CI), Homogeneity index (HI), Gradient Index (GI), and OAR doses.
- Statistical comparisons were performed using Friedman ANOVA and post-hoc Wilcoxon signed-rank tests ($p < 0.05$).

Methods



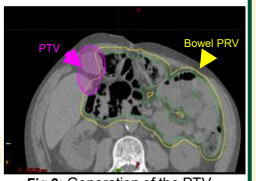


Fig 2: Generation of the PTV-Bowel PRV for plan optimization.

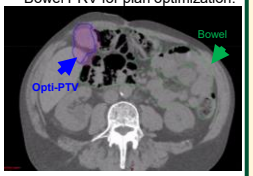


Fig 3: The PTV is cropped away from the bowel.

Results

Fig 4. Scatterplots depict the plan quality metrics V100%, CI, IHI and GI for the three different methods for all 17 patients.

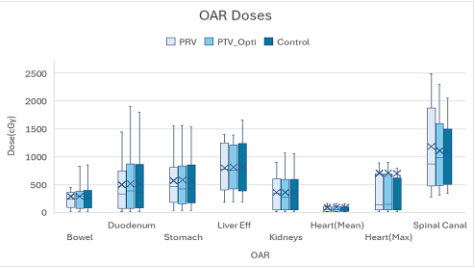


Fig 5. OAR dose comparison for the three treatment planning techniques.

Results

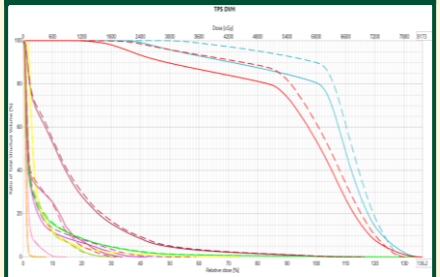


Fig 6: Comparison of PRV-based (solid) and Opti-PTV (dashed) planning methods. The latter utilizes a derivative structure created by subtracting OARs from the PTV.

Metric	P-Value	Significance
V100%	0.035	Yes
CI	0.017	Yes
IHI	0.002	Yes
GI	0.589	No
Heart Max	0.05955	No
Bowel Mean	0.4271	No
Duodenum Mean	0.1615	No
Stomach Mean	0.6625	No
Max Spinal Canal	0.1009	No
Liver Effective	0.12	No
Kidneys Mean	0.7847	No
Body Max	0.3902	No
MU	0.327	No

Table 1. Comparative statistical analysis of planning techniques. Statistically significant results ($p<0.05$) prompted post-hoc Wilcoxon signed-rank testing.

The post-hoc Wilcoxon test was performed and yielded the following results. V100%, CI and IHI were statistically significant. There was an increase in V100% (p-value=0.0004) and CI (P-value= 0.0004) between groups 1 and 2. There was also a significant difference in IHI between groups 1 and 2 (p-value=0.0012) and 1 and 3 (p-value= 0.0021).

Conclusion

- PRVs may not be necessary to protect organs in isotoxic liver adaptive treatment planning.
- PRV usage demonstrated a negative impact on target coverage with negligible improvement in OAR sparing.
- Ethos IOE provides robust priority management; however, supplemental helper structures remain a viable strategy for enhancing coverage.

References

1.) Varian Medical Systems. (2025). *Automated Planning in Ethos 2* (Publication ID: P1035867-330-C)

2.) Pokharel, S., Pacheco, A., & Tanner, S. (2022). Assessment of efficacy in Automated Plan Generation for Varian Ethos Intelligent Optimization Engine. *Journal of Applied Clinical Medical Physics*, 23(4).