Planning strategies for dynamic tumour tracking treatments

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INTRODUCTION

The Vero4DRT linear accelerator (Vero, figure 1) is capable of dynamic tumour tracking (DTT) by panning/tilting its gimbal-mounted head[1]. However, no treatment planning systems (TPS) model the panning/tilting geometry and plans are created, optimized, and evaluated on a single breathing phase CT image. Previously, a method was developed to model panning/tilting and accumulate dose distributions from multiple breathing phases into a 4D dose distribution[2,3]. While this provides an accurate method to confirm the dose to OARs during DTT treatments, it offers no solution during plan creation and optimization to ensure the plan's safety. This work investigates two treatment planning strategies for DTT plans optimized on a single breathing phase to ensure an OAR will be below its dose limit after a 4D dose calculation: the "Boolean OAR" method and the "Aperture Sorting" method.

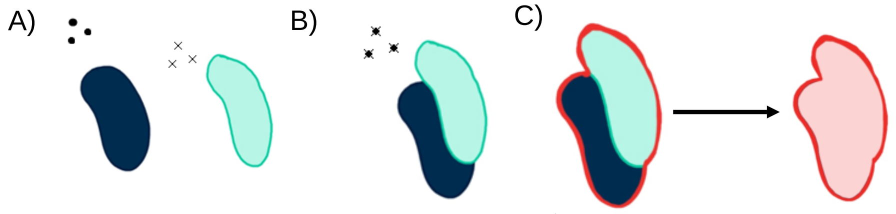
Figure 1: The Vero linac can rotate around the patient's superior-inferior axis and around its vertical axis (ring rotation). The linac head is mounted on a gimbal system to perform DTT.

METHODS

- **1 phantom test case:** CT set to water density, spherical OARs/target added.
- **10 clinical datasets:** CT data from previous liver SABR patients.
- sIMRT plans optimized on breath-hold exhale CT image in the RayStation TPS (RaySearch Laboratories).
- All dose constraints met, planning target volume (PTV) coverage maximized (ideally $V_{100\%} \geq 95\%$).
- 2-phase (inhale and exhale) 4D dose calculations conducted using methods described by *Carpentier et al*[2]

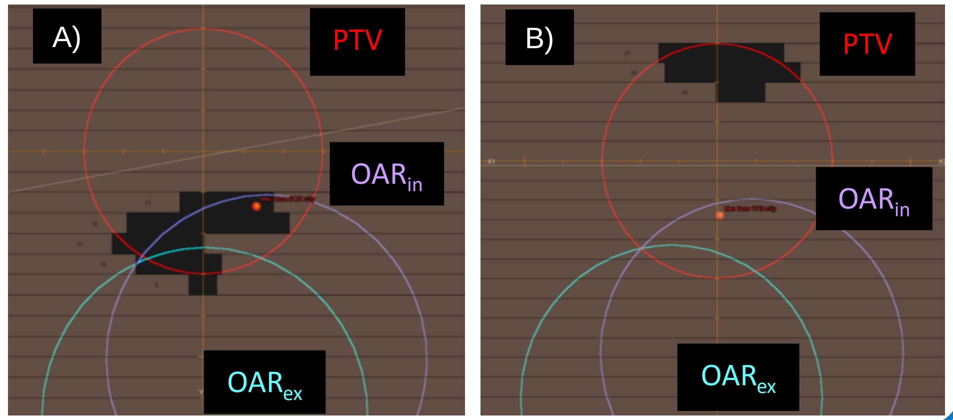
Strategy #1: Boolean OAR method

Figure 2: A) An OAR is contoured on the exhale phase (dark blue) and inhale phase (light blue). B) The inhale phase contour is transformed to the exhale CT by aligning the implanted fiducial markers near the target (x's and circles). C) A union of the contours is created. A new sIMRT plan is optimized on the exhale CT that protects this boolean contour.



Strategy #2: Aperture sorting method

Figure 3: This method determines which apertures contribute more to an OAR's maximum dose on one breathing phase over the other, and assigns that aperture to the phase where it contributes the least dose. A) and B) show the beam's eye view of two different apertures in the same sIMRT plan from the phantom test case. A) This aperture was assigned to the exhale phase since on the inhale phase a larger portion of the OAR is in the beam's eye view. B) This aperture was not sorted as it missed the OAR on both phases.



RESULTS

Phantom test case

	OAR D_{max} (cGy)	PTV $V_{100\%}$ (%)
3D dose calculation **(Original plan, exhale)**	**2762**	**94.4**
4D dose calculation **(No planning strategies)**	**3881**	**94.4**
4D dose calculation **(Boolean OAR method)**	**2038**	**78.9**
4D dose calculation **(Aperture sorting method)**	**2791**	**93.4**

Table 1: The OAR maximum dose and PTV coverage for the phantom test case when no planning strategies were used, and when each planning strategy was used. The OAR's dose limit was 2800 cGy. 15/28 apertures were sorted to the exhale phase during the "Aperture Sorting" method.

10 clinical datasets

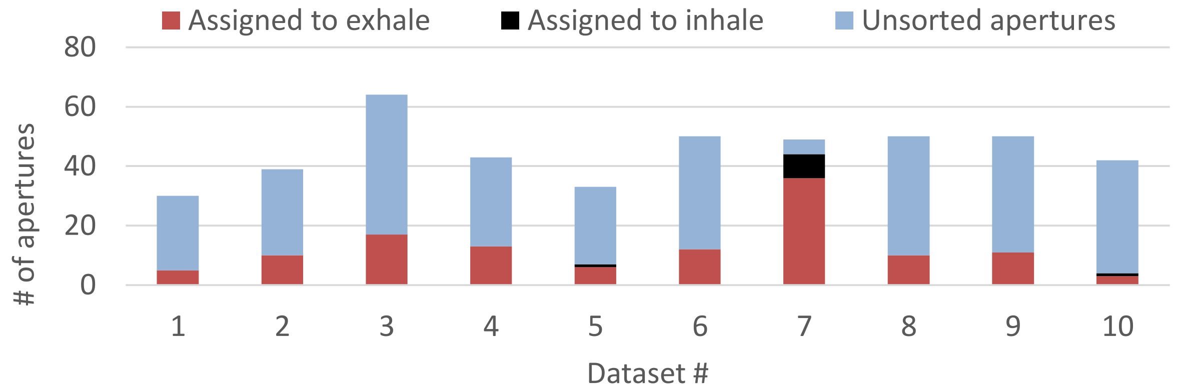


Figure 4: The number of apertures sorted for each clinical dataset using the "Aperture Sorting" method.

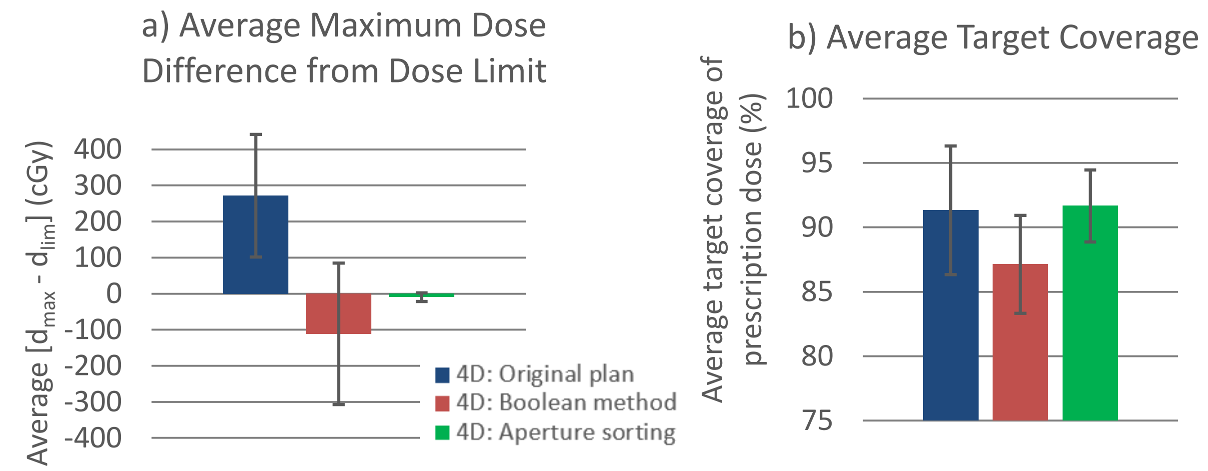


Figure 5: a) The dose limit for each OAR subtracted from the maximum dose to each OAR, averaged over the ten clinical datasets. b) The average target coverage among the ten datasets. Data is reported from 4D re-calculated dose distributions. Error bars represent the standard deviation.

CONCLUSIONS

- 4D planning strategies that are simple to implement can improve an OARs safety during DTT treatments.
- The "Boolean OAR" method is fast and simple to implement, however the reduced target coverage is a sacrifice and sparing an OAR is not guaranteed.
- The "Aperture Sorting" method requires more time to implement, but results in improved OAR sparing while preserving target coverage.

REFERENCES

1. **Takayama K et al**. *Radiotherapy and Oncology*. 93(1):45–49 (2009)
2. **Carpentier, EE. et al**. *Journal of Applied Clinical Medical Physics*, *22*(6) (2021)
3. **Carpentier, EE. et al**. *Journal of Medical Physics*, *48*(1), 50 (2023)