Patient Specific Collision Zones for 4π SRS/SRT

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INTRODUCTION

The **4π method** determines optimised non-coplanar sub arcs for SRS/SRT [1] in order to minimize dose to organs-at-risk (OARs) . The couch-gantry trajectories are informed by calculating the geometric overlap in the beams-eye-view of the PTV and OARs at each treatment angle which forms **an overlap map**. Using the optimisation algorithm MacDonald et al. achieved a 19% decrease to mean dose to the OARs and a 14% reduction of the maximum dose [2]. The algorithm must also navigate around **collision zones** which are combinations of couch and gantry coordinates which may result in a collision between the gantry and couch or patient. Initial works utilized a collision zone **manually measured** on the treatment bed, using a cranial phantom with a 5 cm buffer. Because of the variation in patient's PTV location and size a singular general collision zone is not appropriate for clinical applications.

AIM

- To create a method by which to determine **patient-specific collision zones** for the purpose of determining safe and deliverable 4π trajectories.
- Confirming that the patient-specific trajectories do not significantly change the dosimetric outcomes of 4π SRS.
- Investigate whether **general collision zones** are sufficient for clinical use.
- Determine the accuracy, specificity, and sensitivity of the collision detection algorithm.

METHOD

The collision detection system utilized a point cloud of the patient obtained from the treatment planning CT. The couch and immobilization equipment contours were obtained from CT scans and aligned to the patient contours (Figure 1). A third-party gantry model point cloud was aligned to the patient based on the location of the patient's PTV and expanded to account for a 5 cm buffer (Figure 2). The patient contour was extended to account for the patient's body. Each combination of couch and gantry angles were tested for collision using an OcTree detection method [3].

Eight patient-specific collision zones were calculated, followed by the 4π treatment trajectories as generated by a previously published method [2] for both the general and specific collision zones. The arc trajectories were imported into the Eclipse treatment planning system (v13.6) and inverse optimized with VMAT (PRO v13.6) to clinical standards. The mean and maximum dose to several OARs, conformity index of the PTVs and trajectories were compared. Overlaying the trajectories from the patient's specific map onto the general collision zone map investigated if collisions may have occurred if a general collision zone map was used for delivery. Finally, an end-to-end collision zone comparison test was preformed. A phantom was used to both generate a collision zone and manually measure a collision zone on the unit. These collision zones were overlaid to calculate the accuracy, specificity, and sensitivity.

RESULTS

Effect on dose to OARs and the conformity index

The difference in the maximum and mean dose to the OARS and the conformity index values when comparing the general and patient-specific collision zones, were **statistically insignificant (p > 0.7)**. General and specific collision zones are displayed in Figure 3.a and 3.b.

Are general collision zones sufficient?

At least one possible collision was identified for seven out of the eight patients if the general arc trajectories were delivered. Figure 3.c shows treatment arcs generated using a general collision zone. These treatment arcs overlap with the patient-specific collision zone and thus would lead to collisions.

Accuracy of the collision detection algorithm

		Measured Collision Zone	
		Collision	No Collision
Calculated Collision Zone	Collision	True Positive (TP)	False Positive (FP)
	No Collision	False Negative (FN)	True Negative (TN)

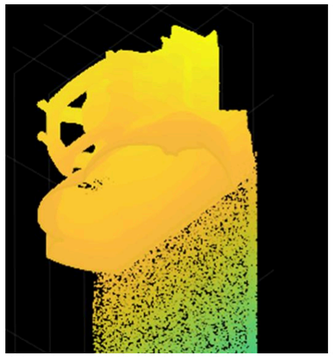

Figure 1: *Patient point cloud, with a Brainlab frameless array, headboard and the treatment couch aligned.*

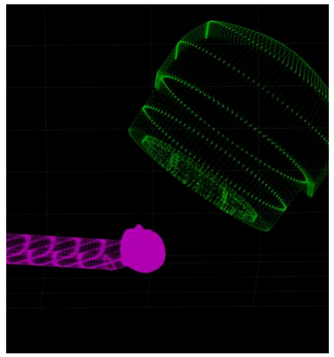

Figure 2: *Patient CT and couch point cloud with the gantry head point cloud aligned.*

$\text{Accuracy} = \frac{TP+TN}{P+N}$	0.929
$\text{Specificity} = \frac{TN}{N}$	0.934
$\text{Sensitivity} = \frac{TP}{P}$	0.916

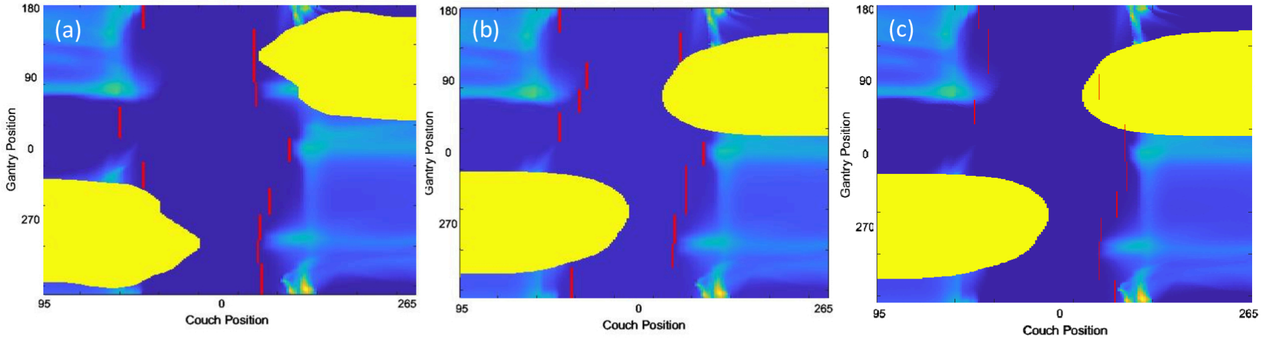

Figure 3: *4π overlap maps demonstrating:*
(a) general collision zone with generated treatment trajectories.
(b) patient-specific collision zone with generated treatment trajectories.
(c) trajectories generated using the general collision zones overlaying the patient-specific collision zones.

CONCLUSIONS

- **No statistically meaningful changes** were observed in the maximum doses, mean doses or conformity index values.
- Seven out of the eight patients would see collisions if the patient-specific arcs were calculated with the general collision zone and would be due to the failure to account for variability in patient size and positioning. This indicates the value of **patient-specific collision zones in insuring the deliverability** of 4π cranial therapy.
- The collision zone algorithm was able to calculate collision zones with **excellent accuracy** as proven by the end-to-end testing.

FUTURE WORK

The next step is to apply 4π to extra-cranial, SBRT, patients. While the collision detection algorithm is complete it can not account for the variation between cranial and extra-cranial patient set-up.

More work will be done to create an algorithm to account for the patient set-up utilized for SBRT.

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ACKNOWLEDGEMENTS

This research is supported in part by BrainLab and the Atlantic Canada Innovation Fund. J Lincoln reports funding from the Canadian Institute for Health Research.

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