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An Automated Non-Coplanar VMAT Planning Study for Dose Escalation in Recurrent Head and Neck Cancer Patients

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INTRODUCTION

Locoregional recurrences occur in 15-50% of head and neck cancer patients who receive primary radiation therapy, many of whom are not candidates for salvage surgery. Highly conformal stereotactic body radiation therapy (SBRT) has shown promising outcomes for unresectable localized recurrent head and neck cancer (rHNC), but the maximum deliverable tumor dose is limited by toxicity to the surrounding previously-irradiated tissues. Even with SBRT, studies have reported severe toxicity rates of over 25% and fatal carotid artery blowout rates as high as 17% when full prescribed reirradiation doses are delivered.[1]

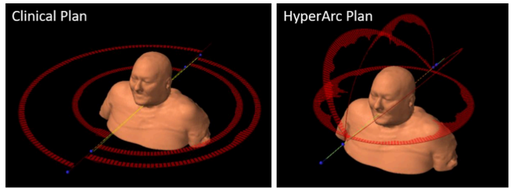
The potential for non-coplanar beam angles to increase dose conformity has been demonstrated in many sites, including the head and neck.[2,3] However, manual non-coplanar beam selection is inefficient and increases the probability of patient-machine collisions. Recently available commercial software (HyperArc, Varian Medical Systems) has made automated non-coplanar VMAT planning and delivery clinically feasible, but its capabilities have yet to be fully explored. This treatment technique has not yet been used for HNC patients, who could greatly benefit from the achievable target dose escalation for improved local control.

AIM

This study explores the ability of the HyperArc technique to escalate the tumor dose in rHNC SBRT plans while minimizing toxicity to adjacent organs-at-risk (OARs). This could potentially increase the probability of local control, especially in cases where the safely-deliverable tumor dose would have otherwise been limited by high OAR doses from initial treatment.

METHODS

Planning: Fifteen rHNC patients were selected from our clinic who were re-irradiated with SBRT to 40 Gy in 5 fractions with mostly partial coplanar arcs. New plans were created using the HyperArc technique (with 4 partial non-coplanar arcs, as illustrated below) to escalate the target dose to 55 Gy while achieving similar OAR doses. Maximum dose constraints were placed on the larynx (≤20 Gy), spinal cord (≤8 Gy), mandible (≤20 Gy), brainstem (≤8 Gy), and skin (≤36 Gy), while also matching the clinical dose to any other OARs.

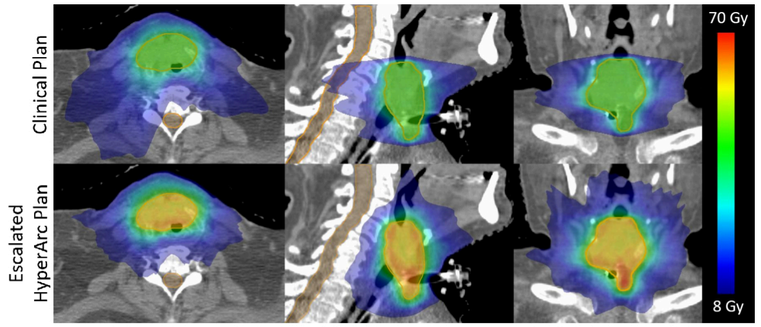


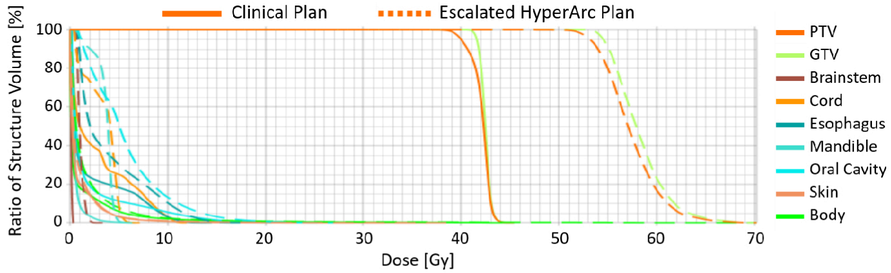
Beam angles for the clinical (left) and HyperArc (right) plans for one patient in the study.

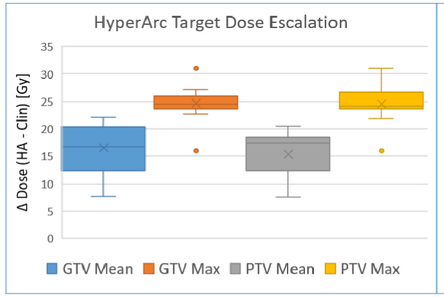
Analysis: The mean and maximum doses to the GTV and PTV, as well as the maximum OAR doses, were compared for the two plan types. The tumor control probability (TCP) for the GTV and normal tissue complication probability (NTCP) for each OAR were calculated using the effective uniform dose model.[4-6] Statistical significance was determined using a paired, two-tailed t-test (5% level).

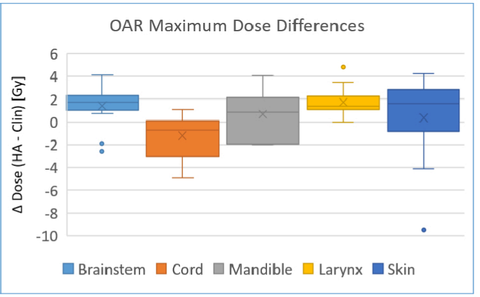
RESULTS

Isodose distributions (right) and dose volume histograms (below) for the same study patient shown in the Methods section.









	Clinical	HyperArc	Difference	Clinical	HyperArc	Difference
	Mean Dose (Gy)			TCP (%)		
PTV	41.6	56.9	+15.4*	-	-	-
GTV	41.9	58.5	+16.5*	28.6	71.4	+42.8*
	Maximum Dose (Gy)			NTCP (%)		
Brainstem	3.5	4.9	+1.4*	0	0	0
Cord	7.2	6.0	-1.2*	0	0	0
Mandible	12.3	12.9	+0.7	1.6	0.6	-1.0
Larynx	18.3	20.2	+1.9*	20.1	21.8	+1.7
Skin	28.0	28.4	+0.4	-	-	-

**Statistically significant difference (paired, 2-tailed t-test, <5%)*

CONCLUSIONS

The HyperArc treatment planning technique achieved significant increases in PTV and GTV mean doses of approximately 37% and 40%, respectively. Clinically equivalent OAR doses were maintained, and any OAR doses exceeding constraints in the clinical plans were matched or reduced in the HyperArc plans. For example, 5 of the clinical plans exceeded the maximum spinal cord dose constraint, compared to only 2 of the HyperArc plans. Although there were slight increases in mean dose to a few OARs, any dose differences <1 Gy per fraction were considered clinically inconsequential. This is in accordance with the protocol for our current prospective clinical trial using the HyperArc technique to treat rHNC patients.

The radiobiological modeling study suggests that treating with the escalated HyperArc plans rather than the conventional clinical VMAT plans could increase the probability of tumor control by approximately 43%. The dose constraints on the cord were tight enough to essentially eliminate the probability of complication in any of the plans, based on the widely used modeling parameters in Emami et al.[6] There were also no significant differences in NTCP for the mandible or larynx, suggesting clinically equivalent OAR doses between the clinical and HyperArc plans.

This study suggests that the HyperArc treatment planning technique can enable significant dose escalation for head and neck SBRT plans while achieving similar OAR doses, potentially improving the local control and overall survival rates for rHNC patients while limiting the risk of treatment-related toxicity. The increased dose conformity demonstrated in this study suggests that HyperArc could also be beneficial for reducing toxicities in a wider population of HNC patients, including those receiving primary radiation therapy and non-escalated reirradiation.

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CONTACT INFORMATION

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