Helical Photon Plans Provide a Fast and Effective Backup for Proton Therapy

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ABSTRACT

This study evaluated the feasibility of helical photon therapy as a rapid backup to proton therapy by comparing dosimetric quality, planning efficiency, treatment delivery, and patient-specific quality assurance across multiple disease sites.

Thirty helical photon and proton treatment plans were generated for 10 patients. Cases were grouped into three categories:

(1) proton therapy provided superior organ-at-risk (OAR) sparing but required longer planning, patient setup, and treatment delivery times;
(2) helical photon and proton plans achieved comparable target coverage and OAR sparing;
And
(3) for superficial tumors, helical photon plans provided superior target coverage and dose conformality with faster treatment delivery.

These findings support helical photon therapy as an effective and rapidly deployable backup for selected proton therapy indications.

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INTRODUCTION

Purpose: This study aims to compare plan quality between helical photon and IMPT proton delivery platforms across multiple disease sites to evaluate whether helical plans could provide an effective and rapid backup to proton therapy.

METHODS AND MATERIALS

Ten patients representing multiple disease sites, including craniospinal irradiation (CSI), head and neck (HN), lung, brain, liver, prostate, pancreas (n = 2), scalp, and chest wall, were included, generating a total of 30 treatment plans. Treatment planning was performed using two commercial treatment planning systems: RayStation (RaySearch Laboratories, Sweden) for both photon and proton plans, and Precision (Accuray, Madison, WI, USA) for helical photon plans. For comparative analysis, cases were grouped into three clinically relevant categories. Proton therapy provided superior organ-at-risk (OAR) sparing, while both photon and proton plans achieved at least 95% clinical target volume (CTV) coverage. All treatment plans were delivered successfully, with an average patient-specific QA passing rate of 97% using the 3%/3 mm gamma criterion for helical photon treatments. Overall, helical photon planning, setup and delivery were faster while maintaining clinically acceptable target coverage and comparable OAR sparing for selected disease sites. These findings suggest that helical photon therapy can serve as an effective, rapidly deployable backup to certain proton therapy plans. Meanwhile, under the identical machine parameters, photon plans generated with Precision demonstrated shorter delivery times than those generated with RayStation.

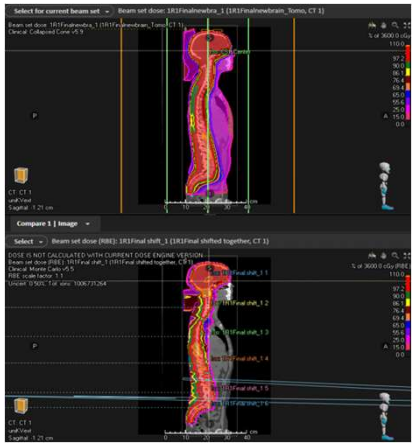

Figure1. The comparison of craniospinal irradiation (CSI) plans using helical photon therapy (top) and proton therapy (bottom) shows that proton therapy provides superior organ-at-risk (OAR) sparing, achieved using a five-junction setup. In contrast, the helical photon plan delivers continuous treatment with a total setup and delivery time of less than 20 minutes.

RESULTS AND DISCUSSION

1. Category 1 (CSI, head and neck, and lung): Proton therapy demonstrated superior organ-at-risk (OAR) sparing. particularly for the heart, lungs, and kidneys. In the unilateral head and neck case, proton therapy also provided improved sparing of the brainstem and oral cavity, while maintaining comparable doses to the spinal cord and parotid glands relative to helical photon therapy.

Table 1. Category1: Proton plans demonstrated superior overall organ-at-risk (OAR) sparing.

Disease site	Modality	Target CTVs	Cord Max (Gy)	Lungs Mean (Gy)	Heart Mean (Gy)	Kidneys Mean (Gy)
CSI (Rx: 3600 cGy)	Photon	95%	41.79	14.76	15.36	24.17
	Proton	95%	43.86	1.98	0.1	0.068
			Cord max	Brainstem max	Oral Cavity	Parotid Mean
HN (70Gy)	Photon	98%	41.89	58.56	45.81	47.89
	Proton	98%	43.80	50.45	28.91	42.08
			Cord max	Lungs V20Gy	Heart	Chest wall Max
Lung (54Gy)	Photon	95%	14.66	8.92%	3.21	54.35
	Proton	95%	26.05	22.58%	8.56	61.51

RESULTS AND DISCUSSION

3. Category 3 (scalp and chest wall): For superficial tumors, helical photon plans achieved superior target coverage and dose conformality compared with proton plans, while also providing shorter treatment delivery times.

Table 3. Category 3: helical photon plans provided superior target coverage and conformality.

Disease site	Modality	Target CTVs	Brain V20Gy< 50 cc	Brain V42Gy< 3 cc
Scalp (Rx: 50Gy)	Photon	99.5%	36.5	2.6
	Proton	95.2%	9.3	0.8
			Lungs V18Gy<40 %	Heart Mean
Chest Wall (42.56 Gy)	Photon	100%	37.2	2.9
	Proton	95.4%	30.4	4.6

2. Category 2 (SIB prostate, pancreas, brain, and liver): Helical photon and proton plans achieved comparable target coverage and OAR sparing, while helical photon plans required shorter planning, setup, and delivery times. (Table 2).

Disease sites	Modality (Photon-1, Proton-2)	TPS 1 or TPS2 (Ray versus Precision)	Dynamic Jaws	Pitch	Delivery Time (sec)	Modulation	Target CTV Coverage: V(100Rx)>95%	Dmax (Gy)	Bladder V65Gy (%) <10%	Rectum V65Gy<10%
SIB Prostate	1	1	2.5	0.4	503	2.8	98.4	75.8	10.2	8.6
(70Gy/50Gy)	1	2			372.7	2.5	97.3	76.5	6.5	5.4
	2	1					96.4	76.4	9.6	7.9
							V(100Rx)>95%	Brain	Chiasm	Optic Nerve
Brain	1	1	2.5	0.4	449	2.7	99.8	30.49	48.72	24.6
(59.4 Gy)	1	2			407	2.5	99.9	26.51	50.95	57.0
									Liver V(30Gy) <30%	Duodenum D (0.03 cc) <55Gy
Pancreas1	1	1	5	0.2	179	2.8	96.5	52.3	14.9	52
(50.4Gy)	1	2			154.9	2.8	99.3	51.1	11.7	51
	2	1					96.4	52.9	8.5	53.2
Pancreas2	1	1	2.5	0.4	605	3.9	97.1	40.7	8.9	37.9
(36Gy)	1	2			444.2	3.2	98.1	37.4	5.1	37.2
	2	1					95	39.9	7.1	37.5
									Kidney_R V(18Gy) <10%	Duodenum V(50Gy) <33cc
Liver	1	1	5	0.2	420	3.5	95.5/93.7	73.6	7.1	2.6
(70Gy/50Gy)	1	2			342.2	3.2	99.5/70.8	76.5	10.2	0.2
	2	1					99.3/99.6	74.4	10.2	3.6

Conclusion

The optimal treatment modality depends on disease site and clinical objectives. Proton therapy remains the preferred modality for cases requiring maximal OAR sparing, whereas helical photon therapy achieved comparable dosimetric quality for selected disease sites with substantially improved planning and treatment efficiency. These findings support helical photon therapy as an effective and rapidly deployable backup option for selected proton therapy indications and provide practical guidance for institutions implementing integrated proton–photon treatment programs.