Comparison of The Radiotherapy Techniques for The Treatment of Ocular Melanoma

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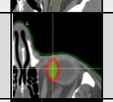
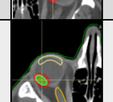
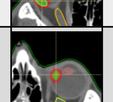
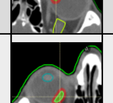
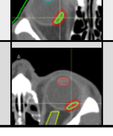
Introduction

Eye plaque brachytherapy and external beam radiotherapy (EBRT) are the most used treatment for ocular melanoma to achieve tumor clearance and prevention of metastases while preserving vision. Brachytherapy uses radioactive seed to deliver radiation directly to treatment area with lower risks to healthy tissues nearby, while external beam radiotherapy techniques, including Gamma Knife (GK), CyberKnife, linear accelerator (LINAC), proton beam therapy (PBT), use high energy beams from multiple angles to precisely aim at the target without surgical procedure that is common in brachytherapy. The purpose of this study is to compare the features of different techniques and the dosimetry that can be achieved by GK, LINAC, PBT and eye plaque brachytherapy for ocular melanoma treatment.

Methods and Materials

Six patients treated with eye plaque brachytherapy (I-125, 75 – 87 Gy in 120 -140 hours) for ocular melanoma were replanned in RayStation treatment planning system (TPS) to generate volumetric modulated arc therapy (VMAT) photon plans and intensity modulated proton therapy (IMPT) plans, and also replanned in GammaPlan TPS to generate Gamma Knife(GK) plans. VMAT, IMPT and GK plans all used hypofractionated stereotactic radiotherapy setting and were prescribed to 50 Gy in 5 fractions. VMAT plans used 2 non-coplanar arcs, while IMPT used 2-3 non-coplanar beams. Replanned targets had comparable GTV to eye plaques plans, but with 2mm PTV margin, while brachy therapy used 2-3 mm margin along orbit wall and submillimeter margin inwards the eye. The goal of replanning was to achieve as low as possible doses on ipsilateral optic nerves and lens with PTV coverage around or greater than 98%. Treatment techniques and the dosimetric metrics, including target coverage, maximum dose to ipsilateral optic nerve and lens, were compared among the four techniques. While our current proton beamlines had no aperture available, simulated aperture was added and tested to reduce lens dose.

Table 1. Patients treated with Eye Plaque.

Patient	Tumor location	Rx to apex vector of tumor (Gy)	Distance from inner sclera (mm)	Implant duration (hr)	BED at Rx point Acute (10)	BED at Rx point Late (3)
1		87	5.7	135.55	145.58	201.08
2		85	10.5	120	144.59	204.31
3		85	5	120	144.59	204.31
4		85	4.7	140	141.00	192.32
5		85	5.5	120	144.59	204.31
6		75	6.2	120	124.93	171.42

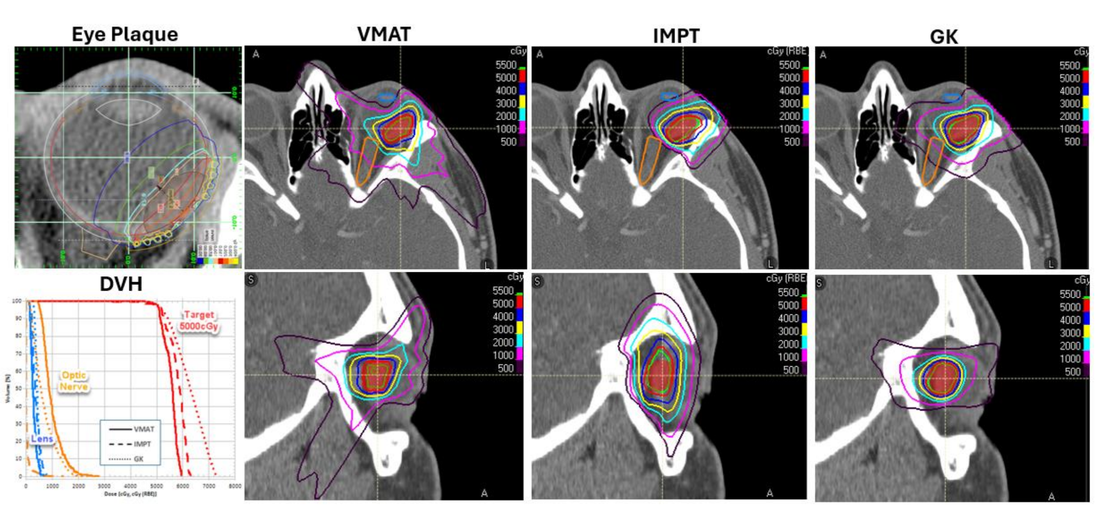


Figure 1. An example to compare VMAT, IMPT and GK plans.

Results

Table 1 shows the information of patient treated with eye plaque brachytherapy. The replanned target volumes were 1.4 cc (range 0.5cc to 3.2cc). The targets located towards medial for 3 patients, and towards lateral for 3 patients relative to optic nerve and lens.

As an example, treatment plans for patient 1 were displayed in Figure 1. The transverse and sagittal views of VMAT, IMPT and GK plans were compared to eye plaque brachytherapy plan. PTV coverage of 98% was met for all replans. The ipsilateral lens and optic nerve doses were also shown in Table 2. The mean maximum dose to ipsilateral optic nerve was 66.7%, 42.6%, 25.3% and 33.9% of prescription dose, and the mean maximum dose to ipsilateral lens was 73.0%, 39.5%, 47.8% and 39.0% of prescription dose, for brachy, VMAT, IMPT and GK plans, respectively. The dose to contralateral eye and optic nerve was 6.3%, 0.2% and 3.4% of prescription dose for VMAT, IMPT and GK plans. With simulated brass aperture, the lens doses in IMPT plans were dropped to less than half of those without aperture for targets >3mm away from lens, and the sinus dose was also dropped significantly for medial targets.

Figure 2 shows the effectiveness of customed aperture to reduce lens dose for patient 1. The maximum lens dose was 6 Gy without aperture, dropped to 3 Gy when apply a simulated aperture.

The robustness of VMAT and IMPT (without aperture) plans was also recorded in Table 3.

Table 2. Dosimetry comparison of VMAT, IMPT and GK plans to eye plaque brachytherapy plans.

	Eye plaque (estimate)		VMAT				IMPT				GK			
Patient	ipsi ON max	ipsi lens max	ipsi ON max	ipsi lens max	contra-eye max	contra-ON max	ipsi ON max	ipsi lens max	contra-eye max	contra-ON max	ipsi ON max	ipsi lens max	contra-eye max	contra-ON max
1	4000	2000	2288	535	281	374	483	668	3	0	1879	558	268	171
2	6000	22000	1952	5732	210	125	630	5455	21	2	1573	5574	276	214
3	6000	1500	2165	354	531	314	655	873	5	0	1702	1049	5	147
4	1000	7000	1104	3250	210	131	62	4673	9	0	555	2019	91	74
5	12000	2500	2872	1587	424	403	3814	1785	10	3	2771	543	219	133
6	40000	2000	2411	379	248	510	1734	803	5	1				

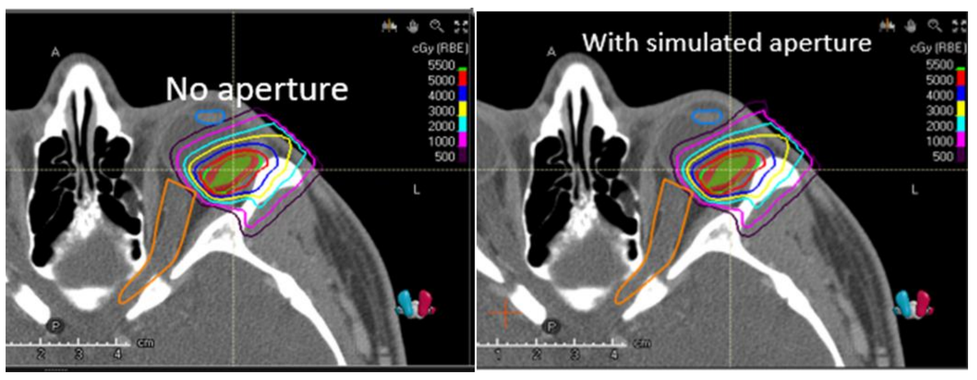


Figure 2. less dose reduction with simulated aperture. Left: The maximum les dose was 6Gy with no aperture; right: maximum dose of lens dropped to 3 Gy with simulated aperture.

Table 3. Robustness analysis for VMAT and IMPT plans.

	1mm robustness		2mm robustness		plan	
	VMAT	IMPT	VMAT	IMPT	VMAT	IMPT
Worst CTV coverage	89.20%	92.20%	83.80%	84.50%	98%	98%
Worst ON dose	2718	999	3363	1111	2288	678
Worst lens dose	640	913	793	1141	535	710

Discussion and Conclusions

External beam radiotherapy and brachytherapy are both effective to treat ocular melanoma. EBRT had the advantages of patient comfort with no surgery procedure involved. Spot scanning IMPT plans with apertures showed superior dose sparing for surrounding organs and lowest dose spread in healthy tissues while still maintaining adequate target coverage. Immobilization of the eyes is essential to ocular treatments when using EBRT techniques.

Contact

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