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Dosimetric and NTCP analysis of hippocampus, parotid and lacrimal glands sparing after whole brain IMRT

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INTRODUCTION

Whole brain radiation therapy is a common treatment modality for patients with extensive disease throughout the brain. When using 3-Dimensional Conformal Radiotherapy (3DCRT), the sparing of normal tissue structures is not often observed. This can lead to increased toxicities and potential lower quality of life after treatment. Of the patients receiving conventional whole brain radiotherapy, around 25% develop dry eye syndrome related to the dose to the lacrimal glands, 35% xerostomia related to the dose to the parotid glands and 25% cognitive side effects from the dose to the hippocampus. Utilizing Intensity Modulated Radiation Therapy (IMRT) various structures, such as the lacrimal and parotid glands, can receive less dose.

PURPOSE

The purpose of this project is to evaluate the difference of IMRT whole brain plans with hippocampal, lacrimal and parotid gland sparing against the clinical plans based on clinical dosimetric metrics and radiobiological indices.

METHOD

Five patients previously treated with 3DCRT were selected to be replanned in Raystation (v.8A RaySearch Laboratories) using IMRT prescribed to 30 Gy over 10 fractions. The plans were optimized following the standards set by the NRG-CC001 protocol and physicians in our clinic. In this study, additional constraints were used for the lacrimal and parotid glands. The planning PTV was generated by taking the whole brain minus the hippocampi with a 5mm expansion. The plans were determined to be acceptable when the PTV received 90-95% of the prescription dose and the OARs were spared per protocol.

The plan comparison was based on the clinical dosimetric goals (Table 1), The dose-volume data for the lacrimal and parotid glands were exported and the normal tissue complication probabilities (NTCP) were calculated using in-house dose-response parameters.

RESULTS

The comparison of the dosimetric metrics acquired from each plan are shown in Table 1. Visually, the differences between the IMRT and 3DCRT plans are shown in Figure 1. The IMRT plans provided large reductions in doses to lacrimal and parotid glands when compared to the 3DCRT plans, and met the minimum goals of hippocampal sparing and overall PTV coverage. More specifically, the largest average differences are observed in the reduction in the V_{15Gy} (82.5% and 89.5%) and V_{20Gy} (42.9% and 53.0%) of the lacrimal and parotid glands, respectively.



Fig 1. Illustration of the clinical (upper left) and optimized (lower left) plans for one of the patients. On the right panel, the dose volume histograms of hippocampus from the corresponding plans is shown (upper), together with the dose difference between the two plans on a transverse plane.).

OAR	Clinical Goal	Patient 1		Patient 2		Patient 3		Patient 4		Patient 5	
		IMRT	3D	IMRT	3D	IMRT	3D	IMRT	3D	IMRT	3D
PTV	$V_{30Gy} \geq 95\%$	90.0	94.0	93.0	95.4	95.0	97.1	95.0	99.4	94.0	99.7
	$D_{98\%} \geq 25$ Gy	28.8	29.5	29.3	29.8	29.6	29.9	29.5	30.5	29.1	30.1
	$D_{2\%} < 37.5$ Gy	31.4	32.3	31.6	32.8	31.5	32.8	31.6	32.1	31.6	32.5
Hippocampus	$D_{100\%} < 9$ Gy	8.9	30.0	9.9	29.9	9.6	29.8	9.7	30.6	9.5	30.1
	$D_{0.03cc} < 16$ Gy	15.8	30.6	16.6	30.4	16.8	30.9	16.7	31.2	16.9	31.0
Lacrimal Lt	$V_{15Gy} < 80\%$	0.6	95.1	0.0	100.0	0.0	88.1	0.0	63.5	0.0	66.5
	$D_{0.03cc} < 15$ Gy	12.8	31.5	7.1	31.7	6.5	32.2	10.8	30.0	8.2	31.1
Lacrimal Rt	$V_{15Gy} < 80\%$	0.0	99.9	0.0	96.6	0.0	100.0	0.0	62.7	0.0	88.4
	$D_{0.03cc} < 15$ Gy	12.9	31.6	8.2	31.6	8.0	32.2	9.2	29.7	8.4	31.6
Parotid Lt	$V_{20Gy} < 50\%$	0.2	45.3	0.0	54.1	0.0	47.0	0.0	50.1	0.2	18.3
	$D_{0.03cc} < 20$ Gy	20.6	30.1	16.2	30.5	12.8	31.7	13.9	30.4	21.3	31.0
Parotid Rt	$V_{20Gy} < 50\%$	0.0	50.3	0.0	47.6	0.5	87.9	0.0	48.3	0.4	32.1
	$D_{0.03cc} < 20$ Gy	19.3	30.6	16.0	30.4	20.4	31.7	14.9	31.7	21.3	30.8
Lens Lt	$D_{0.03cc} < 5$ Gy	4.5	6.3	4.5	11.0	3.9	17.9	4.3	5.1	4.4	4.9
Lens Rt	$D_{0.03cc} < 5$ Gy	4.6	7.8	4.9	11.0	4.3	17.2	5.0	5.1	4.8	4.5
Globe Lt	$D_{0.03cc} < 10$ Gy	10.6	31.5	10.2	31.7	9.8	32.5	10.2	30.0	10.5	31.4
Globe Rt	$D_{0.03cc} < 10$ Gy	10.1	31.5	10.4	31.6	10.3	32.5	10.4	30.7	10.4	31.8
Optics + 3mm	$D_{0.03cc} < 37.5$ Gy	31.3	31.2	31.6	31.9	31.6	32.5	32.0	30.8	31.9	32.2
	$D_{0.03cc} < 30$ Gy	31.3	31.2	31.6	31.9	31.6	32.5	32.0	30.8	31.9	32.2
Lacrimals	NTCP (%)	10.6	29.8	8.8	32.6	8.6	32.5	9.6	18.7	8.8	24.0
Parotids	NTCP (%)	17.0	41.1	15.2	42.6	15.0	48.3	16.2	42.5	15.0	29.3

Table 1. Summary of the dosimetric metrics used during treatment planning for the five patients and two techniques.

The corresponding reductions in the values of NTCP are 18.2% and 25.0% respectively. A considerable reduction in the $D_{100\%}$ and $D_{0.03cc}$ of about 14.2-20.6 Gy is observed for the hippocampus. This increased OAR sparing came a little expense to the PTV coverage. The target coverage ($V_{95\%}$) decrease by an average of 3.7%. None of the plans examined patients had target coverage less than 90% (one had 90% and the rest had at least 93% coverage).

CONCLUSIONS

When compared to 3DCRT, whole brain IMRT plans can provide clinically acceptable plans while significantly sparing the hippocampi, lacrimal and parotid glands. As a result, such plans are expected to reduce the clinically observed complications of dry eyes and xerostomia.

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