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Original Article

Comparison of Dose to CNS Structures: 3DCRT Vs IMRT in Head and Neck Patients Being Treated with Chemoradiotherapy

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ABSTRACT

Introduction: IMRT and 3DCRT are both common head and neck cancer treatment techniques with very different approaches. Although IMRT allows a better dose conformity in PTV, there is much less evidence as to which technique delivers much less dose to OARs especially OARs located outside the PTV which are not considered crucial during planning. Gulliford et.al in their retrospective analysis of phase III parotid sparing radiotherapy trial (PARSPORT) showed statistically significant increase in acute fatigue for those patient treated with IMRT compared to 3DCRT and one possible explanation for this was the dose to CNS structures due to different beam portals. The aim of the present study was to compare the difference in dose distribution to distant OAR (brain stem and cerebellum) for IMRT v/s 3DCRT in series of 30 patients with head and neck cancer receiving radical chemoradiotherapy.
Material and Methods: This was a prospective study of series of 30 cases of head and neck cancer receiving radical chemoradiotherapy by IMRT or 3DCRT with standard fractionation regime, treated in CMC, Ludhiana between Dec 1st 2014 to Nov 30th 2015. For each patient plan was made first for 40 Gy/20F and then boost plan made for 20Gy/10F for both IMRT and 3DCRT. For dosimetric comparison, maximum and minimum dose to OAR (brain stem and cerebellum) was taken.
Results: IMRT and 3DCRT delivers almost equal mean dose to brain stem but it was found to deliver significant higher dose to cerebellum in case of IMRT compared to 3DCRT.
Conclusions: IMRT delivers higher mean dose to cerebellum compared to 3DCRT. This finding needs further larger studies to confirm dose to distant OARs by both techniques.

Keywords*: Head and neck cancer; Intensity-modulated radiotherapy (IMRT); Three-dimensional conformal radiotherapy (3DCRT); Central nervous system dose; Cerebellum; Brainstem; Organs at risk*

INTRODUCTION

In India, HNSCC is the most common cancer in males and fifth most common cancer in females[1], but they forms only 1% to 4% of all cancer in the western world[2]. Radiotherapy plays an important role in the treatment of head and neck cancer. IMRT and 3DCRT are the most common conformal external beam radiotherapy modalities used to treat head and neck cancer. In 3DCRT, 3D anatomic information from diagnostic computer tomographic scan in a forward plan process is used to deliver multiple highly focused beams of radiation to the tumor site[3]. Field can be oblique and non coplanar along with that variation in weight, wedges and shape blocks or multi leaf collimators (MLC) allows accurate and precise conformity of the radiation to the typically irregular tumor volume, theoretically, reducing exposure of surrounding tissue when compared with traditional opposed beam 2DCRT[4].In IMRT, modulation of the beam fluence permits to deliver a non uniform intensity to the target increasing the conformation of high dose to the tumor[5]. Modulation can be achieved by
1) IMRT with static field segment (step and shoot).

2) IMRT with dynamic delivery.
3) Rotational therapy[6,7,8].

Although IMRT has shown superiority over dose coverage, there is still some concern about dose to OARs. However for efficacy end point there is no robust data to advocate IMRT[9,10]. IMRT is a relatively complex technique to perform and variation in daily setup can have adverse impact on success of treatment. Even though this has improved conformity to the target, it may have an undesirable drawback as the large number of fields used in IMRT can potentially lead to higher doses outside the planning treatment volume[11,12,13]. Gulliford et.al in their retrospective analysis of phase III parotid sparing radiotherapy trial (PARSPORT) showed statistically significant increase in acute fatigue for those patient treated with IMRT compared to 3DCRT and one possible explanation for this was the dose to CNS structures due to different beam portals[14,15]. Recently Powell et.al also analyzed fatigue and dose symmetric correlation for nasopharyngeal patients and basal ganglia, pituitary and cerebellum were additional OARs. Significant grade II fatigue was correlated to higher dose to these OARs[16]. Few studies have compared IMRT to 3DCRT in head and neck radiotherapy to evaluate dose to OARs located outside of the PTV[17,18]. The aim of the present study was to compare the difference in dose distribution to distant OAR (brain stem and cerebellum) for IMRT vs 3DCRT in series of 30 patients with head and neck cancer receiving radical chemoradiotherapy.

MATERIALS AND METHODS

This is a prospective study which was conducted in the Department of Radiotherapy, Christian Medical College, Ludhiana between December1st 2014 to November 30th 2015. The study was done in histologically proven cases of head and neck cancer receiving radical chemoradiotherapy.

A contrast enhanced CT simulation was performed in supine position on head and neck board with shoulder leg traction and orfit cast for phase I and phase II separately. Target volume and OARs were contoured according to RTOG guidelines. Both 3DCRT and IMRT plans were generated in each patient for comparative analysis for phase I (40Gy/20F) and phase II boost (20 Gy/10F) using treatment planning system CMS XIO version 4.6.Treatment was delivered using Elekta compact 6MV linear accelerator with 3DCRT or IMRT plan with better coverage of PTV and conforming to the dose constraints for conventional OARs. Treatment planning was performed in accordance with the ICRU reports(50,62 and 83) which recommends a homogeneous dose distribution (range 95% to 107% of the prescribed dose).

Dose constraints for OAR

1) Parotid gland: spare I gland<26Gy
: Dmean≤30Gy
2) Eye max :30Gy
3) Mandible <66Gy
4) Spinal cord <48 Gy

For accurate evaluation of dose distribution to OARs chosen for study (cerebellum and brain stem) apart from standard maximum and mean value, doses were calculated at 0% volume, 30% volume, 60% volume and 90% volume.

Statistical test of significance was done using paired t-test to compare the mean between two techniques for OARs using SPSS software version 20.

RESULTS

Out of the 60 scans in 30 patients, the mean volume of brain stem and cerebellum were 26.9cc and 76cc.The average number of fields used for phase I 3DCRT plan was 4.07 and IMRT plan was 7.76.For phase II 3DCRT and IMRT plan was 2.53 and 5.73.The dose difference between two treatment techniques (DIMRT-D3DCRT), standard deviation and p value is shown in tables below.

Table 1- Mean dose difference (DIMRT-D3DCRT), standard deviation and p value of 40Gy plan for brain stem

DATA OF BRAIN STEM 40GY	PAIRED DIFFERENCES		P VALUE
	MEAN(cGy)	STANDARD DEVIATION	
MEAN DMAX IMRT-MEAN DMAX 3DCRT	+39.20	620.41	0.732
MEAN DMEAN IMRT-MEAN DMEAN 3DCRT	+14.26	395.71	0.845
MEAN D90 IMRT-MEAN D90 3DCRT	+10.33	390.03	0.886
MEAN D60 IMRT-MEAN D60 3DCRT	+53.53	585.38	0.620
MEAN D30 IMRT-MEAN D30 3DCRT	+3.26	570.84	0.975
MEAN D0 IMRT-MEAN D0 3DCRT	+31.46	615.29	0.781

Table 2- Mean dose difference(DIMRT-D3DCRT), standard deviation and p value of 20Gy plan for brain stem

DATA OF BRAIN STEM 20GY BOOST	PAIRED DIFFERENCES		P VALUE
	MEAN(cGy)	STANDARD DEVIATION	
MEAN DMAX IMRT-MEAN DMAX 3DCRT	-35.66	598.06	0.746
MEAN DMEAN IMRT-MEAN DMEAN 3DCRT	-25.50	200.96	0.493
MEAN D90 IMRT-MEAN D90 3DCRT	+11.60	72.17	0.386
MEAN D60 IMRT-MEAN D60 3DCRT	-1.46	110.09	0.942
MEAN D30 IMRT-MEAN D30 3DCRT	+54.10	253.94	0.253
MEAN D0 IMRT-MEAN D0 3DCRT	-41.10	601.34	0.711

Table 1 and Table 2 data shows very close dose margin between two techniques and none of the dose difference is statistically significant, ie the phase I and phase II plan does not show any statistical significant dose difference to brain stem in maximum, mean and dose to the sub volumes between IMRT and 3DCRT technique.

Table 3- Mean dose difference(DIMRT-D3DCRT), standard deviation and p value of 40Gy plan for cerebellum

DATA OF CEREBELLUM 40GY	PAIRED DIFFERENCES		P VALUE
	MEAN (cGy)	STANDARD DEVIATION	
MEAN DMAX IMRT-MEAN DMAX 3DCRT	+395.83	662.98	0.003*
MEAN DMEAN IMRT-MEAN DMEAN 3DCRT	+324.53	749.45	0.025*
MEAN D90 IMRT-MEAN D90 3DCRT	+152.06	443.86	0.071
MEAN D60 IMRT-MEAN D60 3DCRT	157.00	543.43	0.124
MEAN D30 IMRT-MEAN D30 3DCRT	+213.96	683.17	0.097
MEAN D0 IMRT-MEAN D0 3DCRT	415.73	677.45	0.002*

Table 4- Mean dose difference(DIMRT-D3DCRT), standard deviation and p value of 20Gy plan for cerebellum

DATA OF CEREBELLUM 20GY BOOST	PAIRED DIFFERENCES		P VALUE
	MEAN (cGy)	STANDARD DEVIATION	
MEAN DMAX IMRT-MEAN DMAX 3DCRT	+194.10	455.51	0.027*
MEAN DMEAN IMRT-MEAN DMEAN 3DCRT	+81.63	125.12	0.001*
MEAN D90 IMRT-MEAN D90 3DCRT	+25.00	44.06	0.004*
MEAN D60 IMRT-MEAN D60 3DCRT	+42.80	94.41	0.019*
MEAN D30 IMRT-MEAN D30 3DCRT	+90.70	136.20	0.001*
MEAN D0 IMRT-MEAN D0 3DCRT	202.33	445.52	0.019*

As per Table 3 and Table 4,Phase I plan mean dose difference between IMRT and 3DCRT can be seen in all values of cerebellum which are in favor of 3DCRT and shows statistically significance in maximum, mean and D0 dose. In phase II plan, all the values shows statistically significant difference which is in favor of 3DCRT plan.

DISCUSSIONS

The incidental finding by Gulliford et al in retrospective analysis of PARSPORT trial data showed significant increase in acute fatigue in patient treated with IMRT than 3DCRT technique. The possible explanation given to it was the difference in dose to CNS structures. Another study by Powell et al in nasopharyngeal cancer patients tried to correlate grade II fatigue by increased dose to basal ganglia, pituitary and cerebellum. These two studies increased the importance to the dose received by CNS structures in head and neck cancer treatment which was not considered crucial during planning.

Out of the 2 distant OARs considered in this study cerebellum is receiving lesser dose with 3DCRT technique compared to IMRT, ie positive mean dose difference(DIMRT-D3DCRT). This could be attributed to higher number of fields used in IMRT compared to 3DCRT.Brain stem data doesn't show any clear cut dose advantage between the two techniques. As our data subset includes wide variation of primary sites ranging from maxilla and nasopharynx to larynx and hypopharynx dose to OARS also varies markedly. Versus the Powell et al study where only nasopharyngeal patients were studied. These results do not decrease the advantages of IMRT which is more conformal than 3DCRT and less dose to conventional OAR. However data and follow up are limited in case of IMRT. According to our study, 3DCRT may allow better sparing of cerebellum and this is an important factor to consider when planning treatment in head and neck cancer. Particularly, the OAR for which dose was not optimized, might receive a higher dose. It could occur because

during IMRT larger body part is usually irradiated with a small dose and not all OARs can be taken into an optimization process.

Basu et al[19] have also correlated the incidence of fatigue in IMRT patients which could be attributed to the higher doses received by CNS structures during IMRT. Data on dose to distant OARs with IMRT technique is limited as well as the clinical correlation shown in PARSPORT trial with increase fatigue inpatient receiving IMRT which can be correlated to increased dose to structures in brain needs further validation.

CONCLUSION

To conclude, IMRT delivers significantly higher dose than 3DCRT to cerebellum which may translate to fatigue in these patients. This needs validation by prospective studies correlating the clinical effects with the dose to CNS structures in the future.

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