Dosimetric evaluation of carcinoma nasopharynx using Volumetric Modulated Arc Therapy (VMAT): An institutional experience from Western India

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Abstract— *Treatment of nasopharyngeal carcinoma is done by advanced radiotherapy techniques like VMAT (Volumetric Modulated Arc Therapy) where dose to critical organs around tumour is of concern. Present study aimed to describe radiation dose to critical organs in nasopharyngeal cancer patients using VMAT technique. Study was conducted on 10 carcinoma nasopharynx patients treated by VMAT technique at a super-specialty cancer institute in Rajasthan. The structures were contoured using RTOG (Radiation Therapy Oncology Group) guidelines and dose prescription to PTV (Planning Target Volume) was such that 95% iso-dose covered 100% of PTV. Constraints to the OARs (Organs at risk) were as per QUANTEC (Quantitative Analysis of Normal Tissue Effects in the Clinic). VMAT planning was done by double arc using Eclipse (v 10.0.42) treatment planning system. Mean dose to brain stem, spinal cord and optic chiasma were 51.79 Gy, 45.92 Gy and 18.8 Gy respectively. Mean dose to left and right temporal lobes was 22.7Gy and 24.3Gy. Dose to right and left eye were 20.6 Gy and 19.2 Gy while dose to right and left lenses were 5.9Gy and 5.8 Gy respectively. Dose to brain stem, spinal cord, optic chiasma, eyes, lens and temporal lobes were below the dose constraints. VMAT is an effective way to deliver maximum radiation to tumour tissue while providing better sparing of normal tissue and less doses to OARs in carcinoma nasopharynx.*

Keywords: Nasopharyngeal carcinoma (NPC), Volumetric Modulated Arc Therapy, Radiation Therapy Oncology Group.

I. INTRODUCTION

Nasopharyngeal carcinoma (NPC) is endemic in Southeast Asia region. Radiation therapy has been the mainstay treatment of patients of nasopharyneal carcinoma. It is a curative treatment for many patients with non metastatic NPC. It is a radiosensitive tumour but it needs complex treatment plan due to its irregular concave shape, location and close proximity of tumour to the critical organs like spinal cord, brain stem, salivary glands, eyes, optic nerves etc.[1]

In past decade significant progress has been made in field of radiotherapy delivery.[1]. IMRT can provide precise dose distribution in three dimensions. IMRT presents more conformity for irregular target volumes close to critical organs and provides better tumor control and reduces radiation dose to nearby normal tissue. IMRT provides better therapeutic ratio by maximizing dose to the tumour while sparing normal tissue.[2,3] In NPC, IMRT provides better dose distribution to the target volume while lower dose to the OARs (Organs at risk).[4,5] The delivery of IMRT is by a set of fixed radiation beams shaped using

the projection of the target volume. Volumetric Modulated Arc Therapy (VMAT) is another advance in the field of radiotherapy. It is a technique in which IMRT is given in an arc based manner with simultaneously changing multi leaf collimator (MLC) position, gantry position, and dose rate.

This concept has been clinically used in the Eclipse treatment planning software under the name Rapid Arc (RA).

Conventional IMRT delivers fully intensity-modulated radiotherapy fields with a multi leaf collimator (MLC) from a finite number of fixed gantry angles, while RA delivers radiotherapy with MLC that changes the shape of the treatment field dynamically while the gantry rotates around the patient. The purpose of this study was to describe the dose to critical organs in nasopharynx using VMAT technique.

II. METHODOLOGY

A dosimetric study was conducted using medical records of ten patients of nasopharyngeal cancer who were treated with curative intent between January to July 2017. All patients underwent pretreatment evaluation including clinical examination, imaging (MRI/CT) and pretreatment biopsy proof was done. The tumours were staged according to the American Joint Committee on Cancer Staging System. All patients received concurrent chemo-radiotherapy. Radiotherapy was delivered using VMAT technique (rapid arc).VMAT plans of these ten patients were evaluated. Six out of ten patients had advanced clinical stages (stage III/IV)

2.1 Radiotherapy

First of all planning CT scan was done with 5 clamp thermoplastic head and neck or fit with a slice thickness of 3mm, from vertex to below the level of clavicles. Images were then transferred to contouring workstations for contouring of target volumes and critical normal structures. Radiotherapy was delivered with a 6MV linear accelerator using a dynamic multi leaf collimator.

The structures were contoured as per RTOG (Radiation Therapy Oncology Group) guidelines and the dose prescription to PTV (Planning Target Volume) was such that 95% iso-dose covered 100% of the PTV. Gross tumour volume (GTV70) included the primary tumour and any clinically involved lymph node, taking into consideration, physical examination, nasopharyngoscopy findings, CT, PET-CT and MRI. The clinical target volume (CTV70) was created from GTV70 by creating 0.5-1.0 cm margins. The planning target volume (PTV_{70}) was created from CTV by creating 5 mm margin. The CTV 54 included the entire Nasopharynx, posterior ethmoids, posterior third of nasal cavity and maxillary sinuses, inferior sphenoid sinuses, clivus, cavernous sinuses and elective nodal areas. Neck lymph nodes level II-IV was included in CTV54 in all cases. Dose prescription was given according to the ICRU 50 (International Commission on Radiation units and Measurements) recommendations.

Spinal cord, brain stem, optic chiasma, bilateral parotid, eyes, lens and temporal lobes were contoured as OAR. Constraints to the OARs were as per QUANTEC (Quantitative Analysis of Normal Tissue Effects in the Clinic). According to this, maximum dose to spinal cord and brain stem should be less than 45 Gy and 54 Gy respectively. At least one parotid gland mean dose should be less than 26 Gy or volume receiving 30 Gy radiations should be less than 50% of the parotid volume. The planning of all patients was done by double arc using Eclipse treatment planning system. The dose to the critical organs was deduced from the dose volume histogram (DVH).

Table 1 shows the dose limits for OARs.

Table 1
Dose Constraints for OARs and End Points for Nasopharyngeal Carcinoma

Structure	End point	Dose (Gy)	Planning Aim
Brain stem	Necrosis	54	1% of the PRV should not exceed 60Gy
Brain	Necrosis	60	1% of the normal brain should not exceed 60Gy
Chiasm	Blindness	60	0.03cc of the chiasm should not exceed 60Gy
Spinal cord	Myelitis	45	or 1cc of PRV should not exceed 50Gy
Eyes	Blindness	50	Mean dose less than 50Gy
Lens	Cataract	10	As low as possible
Optic nerves	Blindness	54	0.03 cc should not exceed 54Gy
Mandibles	Osteoradio -necrosis	70	1% of the mandible should not exceed 70Gy
Parotids	Xerostomia	26	Mean dose ≤26Gy D50 should be ≤ 30 Gy for one gland
Oral Cavity (excluding PTV)	late mucosal necrosis	40	Mean dose less than 40Gy
Unspecified Tissue		72	1cc of normal tissue outside the PTV should not receive d not receive ≥ 110 % of PTV

PTV-Planning Target Volume; *PRV-Planning Risk Volume; RTOG Protocol 0225

2.2 VMAT plan

Varian Rapid Arc linear accelerator, equipped with a millennium MLC with 120 leaves, was used for treatment. Six MV photon beams were applied to treatment plans with a maximum dose rate of 600MU/min. As a part of inverse planning, the optimization process was done using PRO algorithm (Progressive resolutive optimization).

III. RESULT

The critical structures contoured were the parotids, brain stem, spinal cord, temporal lobes, eyes, lens, optic chiasma and optic nerves. The mean dose to the left and right parotids were 33.7 Gy and 31.4 Gy respectively, while dose to the brain stem, spinal cord and optic chiasma were 51.79 Gy, 45.92 Gy and 18.8 Gy respectively. The mean dose to the left and right temporal lobes was 22.7Gy and 24.3Gy respectively. The dose to right and left eye were 20.6 Gy and 19.2 Gy respectively, while dose to right and left lenses were 5.9Gy and 5.8 Gy respectively. The dose to brain stem, spinal cord, optic chiasma, eyes, lens and temporal lobes were below the dose constraints while the dose to parotids were above the dose constraints probably because most (six out of ten) of these patients were advanced cases. Doses to OARs are presented in Table 2.

Table 2
Details of dose to the organs at risk (OARs)

S. No.	Organ at Risk		VMAT (Gy)
1	Spinal chord	Max	45.92
2	Brain stem	Max	51.79
3	Parotid	R mean	33.7
		L mean	31.4
4	Eye	R max	20.6
		L max	19.2
5	Lens	R max	5.9
		L max	5.8
6	Optic chiasm	Max	18.8
7	Optic nerves	R max	28.4
		L max	27
8	Temporal lobe	R mean	24.3
		L mean	22.7

IV. DISCUSSION

Radiotherapy plays an important role in local nasopharyngeal treatment. NPC patients have better outcomes and life expectancy than other head and neck cancers. Five year survival reaches upto 85% in early stage disease.[6-8] Important point to be considered while planning for NPC is sparing of OARs as many critical structures are in proximity to this three dimensional irregular concave shape tumour. Advances in planning and implementation of RT have focused on delivering max dose to tumour while sparing of surrounding critical structure. VMAT is a novel IMRT technology that has the potential of fulfilling this aim. It allows dose rate, gantry rotation and MLC fiber velocity to be varied during treatment.[9]

There are few past studies that have compared the dosimetry analysis between VMAT and IMRT in head and neck cancer including NPC.[10-12] Vanetti et al[13] in a study showed that VMAT provided a better sparing effect to OARs compared to conventional fixed field IMRT with similar target coverage in head and neck cancers. VMAT reduced the mean dose to the contralateral parotid gland by 13.5% while the decrement of maximal doses to the spinal cord and brain stem were 8.9% and 35.1%, respectively. In present study VMAT was able to achieve dose limits of all OARs except for parotids. In parotid dose limit could not be achieved due to advanced stage (III and IV) in these cases which caused close proximity of tumour volume to parotids.

Results of present study are concordant with those presented by Zheng et al,[14] where in a study of 20 patients of stage III and IV, mean dose radiation in left and right parotid was recorded to be 32.9Gy and 33.4Gy respectively. Similarly in present study the mean dose of right and left parotid were 33.7 and 31.4Gy respectively.

Limitation of present study includes smaller number of patients and difference in the patient tumour volumes.

V. CONCLUSION

Present study supports VMAT as an effective way to deliver maximum radiation to tumour tissue while providing better sparing of normal tissue and less doses to OARs in carcinoma nasopharynx. Further studies with larger sample size and prospective design are required to firmly establish VMAT and its further enhancement.

CONFLICT OF INTEREST

None declared till now.

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