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RESEARCH ARTICLE

A Dosimetric Study on the Impact of Collimator Angles in Nasopharynx Carcinoma using VMAT Planning

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Abstract

Objective: This study aims to rule out the best collimator angle using Monte-Carlo algorithm in Nasopharynx Carcinoma (NPC) with adequate tumour coverage and less OAR. **Methods:** Twenty-nine NPC patients were selected retrospectively. VMAT with dual arc were made with same constraints but with different collimator angles for each patient. Total often plans were created for each patient with a collimator angles of 0;5;10;15;20;25;30;35;40;45 in Monaco Treatment Planning System(TPS) using Monte-Carlo algorithm. Plans were evaluated based on Dosimetric parameters such as target coverage, organ at risk (OAR), conformity index(CI) and homogeneity index(HI). Mean dose (Dmean), and Maximum dose (Dmax) of OARs were also analysed. Data were further evaluated by using SPSS software. **Findings:** The VMAT plans with collimator angles 15°-30° demonstrated better target coverage with a range of (92-94) %±0.7195 for the high-dose PTV and significant reduction in monitor units (MU) by an average of 75 with a CI (0.95-0.96) ±0.0068. Moreover, significant reduction in Dmax of Brainstem and Right optic nerve were obtained with increasing angles. Also,5°-10° showed least PTV coverage and 45° got highest MUs compared to 0°. **Novelty :** This study shows that collimator angles 15°-30° is superior compared with other angles in Ca Nasopharynx VMAT planning by Elekta-HD Versa Linac using Monte-Carlo algorithm.

Keywords: Ca Nasopharynx; Collimator angle; Montecarlo algorithm; Elekta HD Versa Linac; VMAT

1 Introduction

The nasal passageway, also known as the nasopharynx, is a cuboidal open chamber that starts at the posterior choana and descends downward along the airway to the limit of the uvula's free border[1]. Nasopharyngeal carcinoma, the 18th most prevalent cancer in men and the 22nd most common cancer in women, is incredibly rare. It generally develops from the lateral wall and spreads to affect the vertebral bodies and hypopharynx. Because of the nasopharynx's deep position and consequent anatomic proximity to important structures, radiation treatment is currently used to treat stage I and stage II cancer patients alone while concomitant chemoradiotherapy is used to treat stage III to stage IV cancer patients[2,3]. Carcinoma of H&N is a difficult disease site to master[4] due to the fact that this group of cancers includes multiple disease sites. While treating NPC by RT, it's important to spare and safeguard the healthy organs and shorten the course of treatment. With the aid of inverse planning carried out in the convenience of remarkably optimised algorithms and by a variety of beam angles or arcs, intensity modulated techniques (IMRT) are in fact a practical option to achieve appropriate dose distribution that will conform precisely to the target along with reduction of dose to OARs. VMAT is a rotating approach to IMRT[5] that has the advantage of consuming less MU when compared to other treatment methods. It can deliver the dosage to the entire tumour in a single rotation in less than two minutes. It is a suitable modality to use since it avoids critical structures and offers conformal dose distribution around the tumor[5]. Although there have been trials using various collimator angles to treat head and neck malignancies, only a small number have been done specifically for CA Nasopharynx. A study on the impact of collimator angles in LA- nasopharynx cancer in Varian Linac's Eclipse treatment planning system was carried out by Kim et al. and his team utilising the AAA algorithm. Angles between 15° and 20° are useful for treating the tumour, according to the study. Research have shown that Elekta accelerators have higher leaf and interleaf transmission than competing products. The healthy tissues and organs close to the target may also be impacted by this leaking. In order to accurately treat the tumour with a restricted dose to OARs, it is crucial to determine which collimator angle should be used. Nevertheless, no studies comparing ELEKTA HD to Linac were conducted utilising the Monaco Treatment Planning System's Monte Carlo algorithm. Also, the majority of departments treat head and neck tumours with an angle of 0° by default. In order to determine which of these angles is more practical for superior target coverage with OAR sparing for Elekta-HD Versa Linac using Monte Carlo algorithm, this study focuses on improved target coverage of the planning target volume (PTV) with the same constraints and planning parameters but with different collimator angles of 0; 5; 10; 15; 20; 25; 30; 35; 40; and 45.

2 Methodology

This study is a retrospective observational study conducted on the behalf of and under premises of Department of Radiotherapy and Oncology, KMC Manipal. Twenty-nine NPC cases treated during 2017-2021 were selected for the study. The selection of the cases was based on time bound sampling method.

Sampling size: $N = ((Z_{1-(\alpha/2)} + Z_{1-\beta})^2 / C^2) + 3$[6]

$\alpha = 0.05$; $1\text{-}\beta = 80\%$; r= 0.5; $Z_{1-\alpha/2} = 1.96$; $Z_{1-\beta} = 0.8416$

$C = 0.5 \times \ln((1+r)/(1-r))$[7]

$= 0.5 \times \ln((1+0.5)/(1-0.5))$

= 0.5493

Calculated Samples, $N = ((1.96 + 0.8416)^2 / (0.5493)^2) + 3$

= 29

Inclusion criteria: Nasopharyngeal cancer with stage T1, T2 and T3

Exclusion criteria: Palliative cases, T4 stage tumour.

Radiation dose prescription:

PTV 70Gy/35#; PTV 59.4Gy/35#; PTV 56Gy/35#: 18

PTV 70Gy/35#; PTV 59.4Gy/35#: 11

2.1 Computed tomography simulation

A flat couch was used to imitate the headfirst supine posture for the selected cases who had adhered to the Head and Neck protocol. A thermoplastic mould was used to immobilise the patients (ORFIT). After receiving approval from the head of the radiation oncology department at KMC for data extraction, axial CT scans with a thickness of 3mm were obtained for the study. These instances' CT pictures were created with a Philips Brilliance Large Bore CT. After reconstruction, the collected images were further uploaded to the MONACO (Version 1.11) TPS for target volume and OAR delineation inside the CT scans. The margins for GTV, CTV, and PTV were contoured.

2.2 Image registration and contouring

GTV stands for the tumour's grossly visible extent and site. Using an additional margin over GTV to account for the microscopic spread is how CTV is identified. The PTV was then formed with an extra margin over the CTV. Radiation Treatment Oncology Group's standard recommendations were used to identify the OARs, which include the spinal cord, brain stem, left and right parotids, optic chiasma, larynx, and left and right optic nerves (RTOG). The target volume's PTV margin is depicted in Figure 1.

2.3 Treatment planning

The dose provided for PTVs to the chosen cases was 56Gy for low dose-PTV in 35 fractions, which equates to 2Gy/Fraction, 63Gy and 59.4Gy for intermediate-PTV, and 70Gy for HD-PTV. The Monte-Carlo algorithm used by MONACO 1.11 TPS to build VMAT plans for all 29 cases. The same limitations were used to create VMAT plans with two arcs in each example, but the collimator angles increased. At a collimator angle of 0; 5; 10; 15; 20; 25; 30; 35; 40; 45, a total of 10 plans were made for each patient in Monaco TPS using the MC algorithm to be supplied by the Elekta Versa HD Linac Accelerator [7]. Elekta Versa HD has 160 Agility Multi Leaf Collimators with a spatial resolution of 5 mm at isocentre and can deliver five photon energies and six electron energies. All of the resulting plans' grid spaces were maintained at a constant value of 3mm. The fields were then adjusted to comply with PTV. Planning optimizations were carried out while maintaining every limitation that needed to be met and without affecting PTV coverage. All ten of the created plans had the same set characteristics and restrictions.

2.4 Statistical analysis

The DVH parameters of PTV and OAR were analysed using Pearson correlation coefficient (PCC). For null hypothesis testing and testing for statistical significance, Two-Tailed paired t-test is used [8]. The p value set for the study was 0.05 [9]. Plan evaluation was done using SPSS software.

3 Results and Discussion

From the VMAT plans generated it was found there was a slight positive correlation between target coverage with increasing collimator angles, angles 15°-30° showed better tumour coverage compared to other angles by a range of (93-94) % ± 0.7195; (92- 93.7) % ± 0.06051; (90-91) % ± 1.0201 respectively for the PTVs 70Gy/35#; 59.4Gy/35#; 56Gy/35#. While angles 5°&10° showed least PTV coverage for all prescribed PTVs. Likewise, best values for CI were obtained for angles 15°, 20° and 30° by a value of 0.96 ± 0.006809. A significant positive correlation was observed for MUs with increased collimator angles, however, angles 15° and 30° got less MUs of 655 ± 41.6631 while angle 45° received the highest MUs of 782 ± 41.6631. HI with an average of 1.1156 ± 0.00339 was obtained for all the 10 plans. Table 1 shows the comparison of HI, CI and MUs of all the cases.

Table 1. Comparison of HI, CI and Monitor units of all cases

Collimator angles	Hi (mean±sd)	Ci (mean±sd)	Monitor units
ANGLE 0°	1.1139 ± 0.0039	0.948054 ± 0.0068	715.6257 ± 41.6631
ANGLE 5°	1.1149 ± 0.0039	0.950243 ± 0.0068	701.5329 ± 41.6631
ANGLE 10°	1.1177 ± 0.0039	0.951386 ± 0.0068	700.5543 ± 41.6631
ANGLE 15°	1.1129± 0.0039	0.968129 ± 0.0068	653.6821 ± 41.6631
ANGLE 20°	1.1113 ± 0.0039	0.961893 ± 0.0068	712.2843 ± 41.6631
ANGLE 25°	1.1194 ± 0.0039	0.958693 ± 0.0068	734.6736 ± 41.6631
ANGLE 30°	1.1149 ± 0.0039	0.964357 ± 0.0068	695.3364 ± 41.6631
ANGLE 35°	1.1195 ± 0.0039	0.957064 ± 0.0068	765.6636 ± 41.6631
ANGLE 40°	1.1097 ± 0.0039	0.955671 ± 0.0068	781.8679 ± 41.6631
ANGLE 45°	1.1218 ± 0.0039	0.949521 ± 0.0068	782.2843 ± 41.6631

Moreover, significant reduction in maximum doses of Brainstem and Right optic-nerve were obtained with increasing collimator angles by 4507.964 ± 52.3605 and 4652.717 ± 33.3674, respectively. Table 2 shows the statistical comparison of Dosimetric parameters of PTV and OARs. Figure 2 represents maximum doses of PTVs for different angles. No significant reduction of dose was found in sparing other OARs like Spinal cord, Left and Right Parotids, Optic chiasma, Larynx and Oral cavity with different collimator angles. Table 3 represents average mean and maximum dose values of the OARs. Figure 2 shows the DVH for the PTVs for the 10 generated plans.

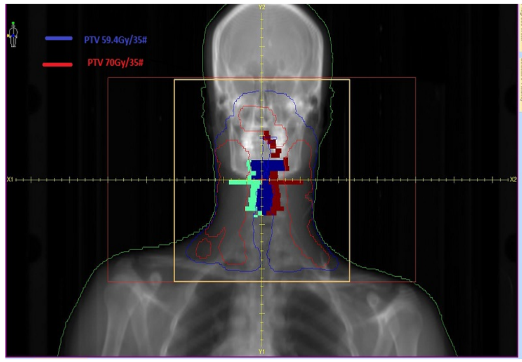

Fig 1. Delineated PTV margin of the target volume

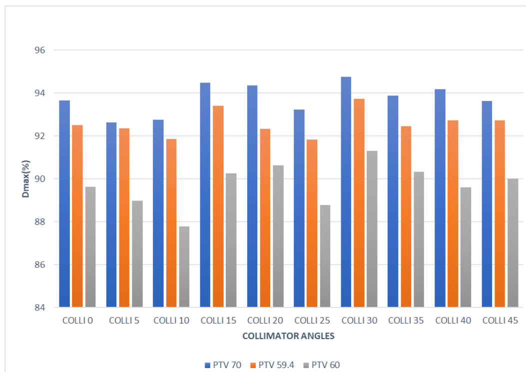

Fig 2. Represents the Maximum doses (%) of PTVs for different angles

Table 2. Statistical comparison of Dosimetric parameters of PTV and OARs

Parametrs	Calculated average value at collimator angles	Pearson correlation coefficient (r)	P (2-tailed) (<0.05 is significant)
HI	1.1156 ± 0.0039	0.275	0.0012
CI	0.9565± 0.0068	0.1754	0.00149
D95% 70Gy (%)	93.75 ± 0.7195	0.403	<0.00001
D95% 59.4Gy (%)	92.59 ± 0.6051	0.2474	<0.00001
D95% 56Gy (%)	89.73 ± 1.0207	0.3953	<0.00001
MUs	724.3505 ± 41.6631	0.7202	<0.00001
SPINAL CORD	3768.86 ± 31.4891	- 0.1073	<0.00001
BRAIN STEM	4507.96 ± 52.3605	- 0.7081	<0.00001
MANDIBLE	6335.58 ± 65.3608	0.7566	<0.00001
LARYNX	4462.26 ± 41.4524	- 0.0495	<0.00001
ORAL CAVITY	4349.10 ± 28.8902	0.5233	<0.00001
OPTIC CHIASMA	4883.78 ± 29.3754	0.4235	<0.00001
LEFT PAROTID	3644.45 ± 33.7354	0.1466	<0.00001
RIGHT PAROTID	3285.99 ± 20.6361	0.2481	<0.00001
LEFT OPTIC NERVE	4772.304 ± 44.1867	0.085	<0.00001
RIGHT OPTIC NERVE	4652.72 ± 33.3674	- 0.7378	<0.00001

Table 3. Average Mean and Maximum dose values for OARs cGy

Collimator Angles	Spinal Cord Max ± SD	Brain Stem Max ± SD	Optic Chiasma Max ± SD	Left Optic Nerve Max ± SD	Right Optic Nerve Max ± SD	Larynx Mean ± SD	Oral Cavity Mean ± SD	Left Parotid Mean ± SD	Right Parotid Mean ± SD
0°	3765.375 ± 31.4891	4500.843 ± 52.3605	4913.6077 ± 29.3754	4787.878 ± 44.1867	4705.5385 ± 33.3674	4470.95 ± 41.4524	4338.878 ± 28. 8902	3702.8819 ± 33.7354	3296.14 ± 20.6361
5°	3726.0231 ± 31.4891	4568.75 ± 52.3605	4840.7692 ± 29.3754	4815.067 ± 44.1867	4645.1154 ± 33.3674	4505.833 ± 41.4524	4356.978 ± 28. 8902	3581.6091 ± 33.7354	3277.3 ± 20.6361
10°	3823.2539 ± 31.4891	4535.236 ± 52.3605	4886.8077 ± 29.3754	4797.1 ± 44.1867	4681.6692 ± 33.3674	4493.875± 41.4524	4278.733 ± 28. 8902	3636.6273 ± 33.7354	3237.87 ± 20.6361
15°	3772.0308 ± 31.4891	4564.35 ± 52.3605	4862.6231 ± 29.3754	4725.8 ± 44.1867	4679.0692 ± 33.3674	4451.85 ± 41.4524	4339.722 ± 28. 8902	3632.8637 ± 33.7354	3290.64 ± 20.6361
20°	3739.8923 ± 31.4891	4496.55 ± 52.3605	4853.1462 ± 29.3754	4676.933 ± 44.1867	4674.2538 ± 33.3674	4391.833 ± 41.4524	4336.322 ± 28. 8902	3659.3546 ± 33.7354	3288.89 ± 20.6361
25°	3810.7616 ± 1.4891	4548.421 ± 52.3605	4848.5154 ± 29.3754	4740.856 ± 44.1867	4630.3462 ± 33.3674	4450.867 ± 41.4524	4380.9 ± 28. 8902	3616.1636 ± 33.7354	3299.36 ± 20.6361
30°	3787.0231 ± 31.4891	4529.479 ± 52.3605	4905.4 ± 29.3754	4783.267 ± 44.1867	4660.4846 ± 33.3674	4442.2 ± 41.4524	4364.622 ± 28. 8902	3639.4 ± 33.7354	3306.84 ± 20.6361
35°	3774.3846 ± 31.4891	4485.457 ± 52.3605	4908.2923 ± 29.3754	4796.656 ± 44.1867	4599.4231 ± 33.3674	4437.867 ± 41.4524	4365.089 ± 28. 8902	3659.0364 ± 33.7354	3303.81 ± 20.6361
40°	3747.0308 ± 31.4891	4442.514 ± 52.3605	4906.3846 ± 29.3754	4814.233 ± 44.1867	4613.2231 ± 33.3674	4439.158 ± 41.4524	4373.144 ± 28. 8902	3635.4909 ± 33.7354	3267.4 ± 20.6361
45°	3742.8462 ± 31.4891	4408.036 ± 52.3605	4912.2154± 29.3754	4785.256 ± 44.1867	4638.0462 ± 33.3674	4538.167 ± 41.4524	4356.622 ± 28. 8902	3681.1 ± 33.7354	3291.64 ± 20.6361

Nasopharynx carcinoma is a head and neck disease that requires expert care because it is close to numerous vital organs. If treatment is unsuccessful despite successfully treating the tumour, it may be due to improper planning that results in underdoing the tumour and overdosing the vital organs, which causes total organ failure or renders the patient bedridden for the rest of his or her life. The VMAT treatment method is used to treat Ca. Nasopharynx because it has demonstrated good results in curing the tumour while causing the least amount of damage to the surrounding normal tissues. For the majority of head and neck tumour treatments, collimator angles of 0° are used.

Angles 15°–20° demonstrated the optimum target coverage and conformity in the study by Yong Ho Kim et al. comparing the impact of collimator angles on VMAT plans developed for patients with Ca Nasopharynx in VARIIAN LINAC states[(10)], [(11)]. Yet, higher angles resulted in higher dosages being absorbed by OARs. Angle 25° gave the highest value for HI, whereas 0° revealed the worst[(10)]. According to the findings of our investigation, plans created with collimator angles of 15° to 30° adequately covered tumours while restricting dosage to OARs. Also, the created plans did not differ significantly according to plan evaluation indices like CI and HI. Later, research by F. Y. Dimitri et al. evaluated the double arc with collimator, double arc, and single arc[(12)] VMAT plans for 10 patients with NPC and found that the double arc VMAT approach with collimator[(13)] had improved target coverage and OAR sparing. A brand-new integrated optimization technique for VMAT was put out by Qihui Lyu et al. and his group, taking into consideration dynamic collimator angles during the arc rotation[(14)]. The article comes to the conclusion that SC-VMAT with three full arcs was inferior in dosimetry to DC-VMAT with a single arc[(15)]. Colli-VMAT plans with smaller angular sections[(16)] have comparable target coverage and spare healthy tissues in comparison to Std-VMAT plans[17], according to analysis by Beom Seok Ahn et al. In the same[16], a precise substantial decrease in total MUs was also noted.

According to our analysis, the total number of MUs had a positive connection with rising angles, with the angles 15° and 30° having the fewest MUs in comparison to 0°. Other organs, such as the Spinal Cord, Larynx, Left and Right Parotids, Optic Chiasma, Left-optic nerve[18], and Oral Cavity, did not experience any alterations; however, Dmax of the Brainstem and Right-optic nerve[18] demonstrated adequate dose decrease with higher angles. Angles 15°–30° saw a 2% increase in tumour coverage and a reduction of 70 MUs in comparison to other angles. This may be due to proper OAR shielding allowing the MLCs to confirm the tumour with greater accuracy. In contrast to angle 0°, angle 45° provided the patient with a higher total dosage while increasing MU by 100. In contrast to all other angles, angles 5° to 10° demonstrated the least target coverage. The fact that all 10 set plans for each patient were created using the same planning parameters, such as the gantry angle, grid size, etc. with collimator angles not being evaluated, could be cited as a study's drawback. More study is required on this issue.

4 Conclusion

The results of our study's data collection show that VMAT plans with collimator angles of 15° to 30° are the gold standard for treating nasopharynx cancer because they can deliver precise, effective conformal dose to the tumour target volume without significantly increasing dose to OARs in Elekta HD Versa Linac. Compared to other angles, these angles maximise target coverage while using fewer MUs and safeguard normal tissues and organs. This study will assist radiotherapy departments in using various angles to treat the tumour with a hopeful outcome as the majority of radiotherapy departments treat Head & Neck cancers using collimator angle 0°.

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