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A Dosimetric comparison between VMAT And IMRT planning techniques for head and neck cancers: A prospective observational study

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Abstract

Head and neck cancer (HNC) is a disease that is heterogeneous in nature, encompassing a diverse array of tumors that originate in the mandible, oral cavity, pharynx, larynx, nasal cavity, paranasal sinuses, and salivary glands. Globally, head and neck malignancies are the sixth most prevalent neoplasm. Approximately 60% of patients present with locally or regionally advanced disease, typically requiring combined modality therapy that includes surgery, radiotherapy, and either chemotherapy or no chemotherapy. Chemoradiotherapy is the established standard of care for patients with inoperable disease or patients for whom surgery would result in unacceptable morbidity. Current radiation techniques limit the dose due to both acute and late toxicities, as well as the complex anatomy of the head and neck region. There is a need for highly conformal techniques that reduce the dose to organs at risk while ensuring adequate target coverage.

Keywords: Cancer; VMAT; IMRT; Chemotherapy; Dosimetric comparison

1. Introduction

Head and neck cancer (HNC) is a disease that is heterogeneous in nature, encompassing a diverse array of tumors that originate in the mandible, oral cavity, pharynx, larynx, nasal cavity, paranasal sinuses, and salivary glands. Head and neck malignancies are the sixth most prevalent neoplasia worldwide, accounting for 6% of all cancer cases and causing approximately 1–2% of tumor-related deaths. Annually, there are over 650,000 cases and 330,000 fatalities. In 2018, India diagnosed approximately 1.2 lakh cases of lip and oral cavity malignancies, accounting for 10.4% of all new cancer cases and ranking as the second most frequently diagnosed cancer. Males are substantially more impacted than females, with a ratio that ranges from 2:1 to 4:10... In 2018, lip and oral cavity malignancies were the most frequently diagnosed cancers in males and the fourth most frequently diagnosed cancer in females in India. The primary risk factors associated with head and neck malignancies are tobacco use, alcohol consumption, human papilloma virus infection (HPV) (for oropharyngeal carcinoma), and Ebstein-Barr virus infection (EBV) (for nasopharyngeal carcinoma). People who have cancer in their head or neck may develop second primary neoplasms in the head and neck, lungs, esophagus, and other areas that share these risk factors. This is because these carcinogens may affect the epithelium of the whole aerodigestive tract. Ages 18 to 22 Over 90% of these tumors are histologically classified as squamous cell carcinoma, or variant. The group of diseases overall is linked to distinct anaetiology and treatment. The different ways used in therapy for head and neck cancer are determined by the location of the tumor, stage, personal patient features, local institutional competence, and/or perceived relative morbidity of each treatment option. Morbidity is also a movable goal, with changing radiation (RT)/systemic treatment and less invasive surgery. About thirty to forty percent of all head and neck cancer cases have early-stage illness (stage I or II); hence, single-modal treatment with surgery or radiation is usually advised for these patients and produces comparable survival. The remaining patients, approximately 60% of who present with locally or regionally advanced illness, typically receive advice for mixed modality treatment. Although concurrent chemoradiotherapy is the accepted standard of treatment for patients with inoperable illness or those for whom surgery would be linked to unacceptable morbidity, optimal treatment for locally advanced head and neck cancer

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remains a problem. External beam radiation, either with or without chemotherapy, is the primary treatment technique; cisplatin is the most commonly used therapeutic drug. We treat carefully and locally advanced cases of tumors developing in the nasopharynx, oropharynx, hypopharynx, and larynx with definite-purpose radiation. The architecture of the extremely complex head and neck area, which includes bony structures, soft tissues, and air spaces, sometimes limits the dosage in current radiation treatments, leading to both immediate and late side effects. From two-dimensional radiation (2D) to three-dimensional conformal radiotherapy (3D-CRT), radiotherapy for head and neck tumors has progressed and become ever more complicated. Without much focus on protecting normal tissues, conventional radiation consists of portals based on 2-D imaging. The cornerstone for 3D-CRT was the growing use of CT imaging for target volume delineation, which produced accurate radiation treatment to afflicted locations while sparing normal tissues. The introduction of IMRT transformed the radiation technique. It is a developed form of three-dimensional conformal radiation that uses computer-optimized inverse treatment planning and computer-controlled multi-leaf collimators. These methods allow the intensity of radiation to be controlled so that, at the same time, the dose to the surrounding normal tissues is significantly lowered, while a larger radiation dosage may be administered to the targets with greatly conformal target volume coverage. We used Volumetric Modulated Arc Therapy (VMAT) to avoid the negative effects of IMRT. VMAT is a commonly used term for the delivery of a rotatable cone beam with varying shape and intensity. A novel VMAT method called Rapid Arc (RA) may generate very conformal designs in a short period of time. Target coverage and normal tissue sparing have shown both VMAT's and IMRT's equivalent efficacy. Nonetheless, VMAT's far shorter treatment duration is very helpful for a busy radiation oncology department like ours.

2. Materials and Methods

Study Site Mahavir Cancer Sansthan and Research Centre, Phulwari Sharif, Patna. This is a charitable hospital run by the Mahavir Mandir Trust. This pioneering institute in Bihar provides treatment to cancer patients from all over the state and surrounding areas. Our institution is one of the very few in Bihar that treats cancer patients with advanced radiotherapy techniques at an affordable cost.

The study population consisted of patients receiving definitive irradiation for head and neck cancers at the Radiation Oncology department of Mahavir Cancer Sansthan, Patna.

STUDY DESIGN The study was designed as a prospective observational double arm study for patients undergoing radiotherapy for head and neck cancers. This study was designed between intensity-modulated radiotherapy (IMRT) and VMAT treatment techniques. Two plans were made for each patient, one using IMRT and the other using VMAT, so that the two groups—group A (IMRT) and group B (VMAT)—were similar in their baseline characteristics. The Institutional Scientific Board and Ethics Committee approved this study.

2.1. Sample Size

Throughout the research time, I intended to pick 64 patients; however, this paper will present data on just 48 patients, with 24 allocated to IMRT and 24 to VMAT. We predicated our sample size computation on the dose-to-target volume across two groups.To calculate the number of participants needed for this study, the significance level was set at 95% (a = 0.05), and the power of the test was set at 90% with a type II error (b) of 0.10. A previous study found that the mean does conformity with CI95% was 0.021 in the double arc RA group and 1.05±0.057 in the IMRT group.Statistical testing will be conducted with the statistical package for the social science system, version SPSS 17.0. Continuous variables will be presented as mean ± SD or median if the data is unevenly distributed. We will express categorical variables as frequencies and percentages. The comparison of continuous variables between the groups will be performed using the student's t test. Nominal categorical data between the groups will be compared using the chi-squared test or Fisher's exact test as appropriate. Non-normal distribution continuous variables will be compared using the Mann-Whitney U test. For all statistical tests, a p value less than 0.05 will be taken to indicate a significant difference.

2.2. Methodology

- All 48 cases (24 for each technique) achieved clinically acceptable IMRT and VMAT plans.
- A total of 48 patients with head and neck cancer were taken for the study from Mahavir Cancer Sansthan

2.3. Radiation Oncology Department

- Consent was taken from each patient.
- A full-fledged history taking and clinical examination was done for each patient, and staging was done according to AJCC 8th edition staging system.
- The patient selection was done according to the eligibility criteria mentioned as follows:

2.4. Pretreatment workup

- Biopsy was done in every case.
- Complete blood count
- Renal function test
- Liver function test
- Chest X-Ray PA view
- CECT face and Neck
- Other optional tests as required

2.5. Eligibility Criteria

2.5.1. Inclusion criteria

- Early and locally advanced, biopsy proven squamous cell head and neck carcinomas (oropharynx, larynx, hypopharynx, nasopharynx)
- No evidence of distant metastasis
- Age between 20 to 65 years
- Karn of sky Performance Status > or = 70
- No significant medical contradiction to the administration of concurrent Cisplatin

Hematologic, renal and hepatic function as follows:

- Haemoglobin > or = 10gm/dl
- Total leukocyte > or 4000/mm3
- Platelet count or 1, 00,000/mm3
- Serum creatinine < or 1.5 times the upper normal limit
- Serum bilirubin < or 1.5 times the upper normal limit

2.6. Exclusion criteria

- Poor general condition and Karnofsky Performance Status < 70
- Metastatic disease outside head and neck
- History of prior surgery, radiotherapy or chemotherapy
- Patients with histology other than squamous cell carcinoma
- Presence of a synchronous double primary

2.7. Treatment Plan

2.7.1. Patient selection, immobilization and simulation

- 24 patients undergoing irradiation for head and neck cancers with definitive intent were selected for the study.
- Patients were aligned in supine position and immobilized on a head rest with a thermoplastic mould. All patients were scanned from skull vertex to upper mediastinum with slice thickness of 3mm for IMRT and VMAT.
- Contrast enhanced CT scans, were taken. CT images were then transferred to the contouring work stations (SOMAVISION) and planning work stations.

2.8. Radiotherapy treatment planning

2.8.1. IMRT planning

For conventional IMRT, treatment planning with 7 fields equidistantly spaced was performed on Eclipse Planning System with beam energy of 6MV X-rays. The IMRT optimization engine computes optimal fluence maps from dose volume constraints derived from the general planning objective. Optimization was done by exploiting interaction window with different objectives and priorities. Optimal fluence maps were then converted by a leaf motion calculator into actual fluence maps which were deliverable using a multi-leaf collimator.

2.8.2. VMAT planning

Similar to IMRT plans, beam energy of 6MV photon Bearn was used in VMAT planning system. Single arc VMAT plan utilizes full gantry rotation (gantry angles from 179 to 181 degrees) and double arc consists of 2 co-planar arcs with the

first arc in clockwise and the other arc in counter clockwise direction (gantry angles from 181 to 179 and 179 to 181 degrees, respectively). Double arc plans were used in this study because planning studies comparing SA to DA VMAT plans were inferior to DA plans in terms of conformity, target coverage, dose homogeneity and OAR sparing (Guckenberger et al., 2009; Bertelsen et al., 2010[8]).

3. Observation and Results

This study was conducted by the Department of Radiation Oncology at Mahavir Cancer Sansthan, Phulwarisharif, Patna, from September 2023 to March 2024. This study was conducted by the Department of Radiation Oncology at Mahavir Cancer Sansthan, Phulwarisharif, Patna, from September 2023 to March 2024.

Each patient received two plans, one using IMRT and the other VMAT, to ensure that the baseline characteristics of the two groups—group A (IMRT) and group B (VMAT)—were similar. We then compared the dose volume histograms of IMRT and VMAT in terms of PTV coverage, monitor units used, treatment time, OAR sparing, and integral dose to OARs.

3.1. Age distribution

Table 1 Age distribution of the study group

AGE (Years)	Numberofpatients(N)	Percentage (%)
>25-35	2	8.3%
>35-45	4	16.67%
>45-55	7	29.17%
>55-65	11	45.8%
TOTAL	24	100%

Most of the patients fall in the age group of > 55-65 years. The median age is 55 years.

3.2. Sex distribution

Table 2 Sex distribution of the study group

SEX	Numberofpatients (N)	Percentage (%)
F	6	25%
M	18	75%
TOTAL	24	100%

The male: female ratio in the study group was 3:1.

3.3. Dosimetry

Table 3 Comparison of the two group's interms of dosimetric outcomes for PTV70Gy

Dosimetric outcomes FORPTV 70GY	IMRT	VMAT	p-value
	Mean±SD	Mean±SD	
D98%(Gy)	65.36±0.85	65.69±0.94	0.200
D2%(Gy)	72.12±0.62	72.09±1.42	0.922
CI95%	0.97±0.01	0.96±0.02	0.289
HI	0.11±0.01	0.09±0.02	0.004

Target coverage was almost similar between the two groups. D98%Gy for the IMRT group was 65.36 ± 0.85 and was 65.69Gy ± 0.94 for the VMAT group and the difference was not statistically significant (p=0.2). D2%Gy was 72.12 ± 0.62 for the IMRT group and 72.09 ± 1.42 for the VMAT with the difference not being statistically significant (p=0.92).

The conformity index was slightly better for the IMRT group (0.97 ± 0.01) than the VMAT group (0.96 ± 0.02) but this was not statistically significant (p=0.289).

The homogeneity index of the VMAT group (0.09 ± 0.02) was superior to that of IMRT group (0.11 ± 0.01) with a statistically significant p value of 0.004.

Table 4 Comparison of the two groups in terms of dosimetric outcomes for PTV63Gy

DOSIMETRICOUTCOMES FOR PTV63Gy	**IMRT**	**VMAT**	**P VALUE**
	MEAN±SD	MEAN±SD	
D98%(Gy)	59.99±1.62	59.27±2.30	0.220
D2%(Gy)	64.71±1.73	64.70±2.04	0.989
HI	0.12±0.03	0.09±0.04	0.002

Target coverage using the two techniques was almost identical. D98%Gy for the IMRT group was 59.99Gy±1.62 and 59.27Gy±2.30 for the VMAT group, but the difference was not statistically significant (p = 0.22). The D2% was 64.71 ± 1.73 for the IMRT group and 64.70 ± 2.04 for the VMAT group, and there was no statistically significant difference between the two groups in terms of this parameter (p = 0.0989).

The homogeneity index of VMAT group (0.09 ± 0.04) was superior to that of IMRT group (0.12 ± 0.03) with a statistically significant p value of 0.002.

Table 5 Comparison of two groups in terms of MUs and treatment time

	IMRT	**VMAT**	**Pvalue**
	MEAN±SD	**MEAN±SD**	
MUs	1651.12±218.43	456.08±48.30	<0.001
TREATMENT TIME (min)	7.34±1.02	2.99±0.33	<0.001

We found that the average number of MUs (±SD) needed to give 200cGy per fraction was 1651.12±218.43 for IMRT plans compared to 456.08±48.30 for VMAT plans (p<0.001). There was also a statistically significant reduction in treatment time with VMAT plans (2.99 min ± 0.33) as opposed to IMRT plans (7.34 min ± 1.02) with a p value of <0.001.

Table 6 Comparison of the two group in terms of Dosimetry to PRV spinal cord

PARAMETERS	**IMRT**	**VMAT**	**pValue**
V10	65.13±17.69	59.04±15.88	0.177
V20	31.29±17.06	54.45±14.67	0.138
V30	39.93±10.78	33.5±14.77	0.035
V40	6.19±6.18	3.37±3.36	0.048
V50	0.86±1.41	0.11±0.35	0.007
V60	0.25±0.82	0±0	0.077
V70	0.08±0.39	0±0	0.317
Mean dose(Gy)	26.65±3.88	26.08±4.14	0.392
Dmax(Gy)	49.45±3.51	46.89±3.43	0.006
Integral Dose(GyL)	1.76±6.66	0.33±0.158	0.788

The maximum dose to the PRV spinal cord (D_{max}) was statistically significantly reduced with VMAT plans (46.89 ± 3.43) as compared to IMRT plans (49.45 ± 3.51) (p = 0.006). The parameters V30, V40, and V50 (in cc) were also statistically significantly higher for IMRT than VMAT plans (39.93±10.78, 6.19±6.18, 0.86±1.41 vs. 33.5±14.77, 3.37±3.36, 0.11±0.35; p = 0.035, 0.048, 0.007, respectively).

The V20 (cc) was found to be higher for the VMAT group (54.45± 14.67) than the IMRT group (31.29± 17.06), but the p value of 0.138 was not statistically significant for this.

The IMRT group had higher V10, V60, and V70 values, as well as a higher mean dose (Gy) and integral dose (Gy L) to the PRV spinal cord compared to the VMAT group (65.13±17.69, 0.25±0.82, 0.08±0.39, 26.65±3.88, 1.76 ± 6.66 vs. 59.04 ± 15.88, 0±0, 0±0, 26.08±4.14, 0.33±0.158), but the differences were not statistically significant (p=0.177, 0.077, 0.317, 0.392, 0.788, that is).

Table 7 Comparison of the two groups in terms of Dosimetry to brain stem

PARAMETERS	**IMRT**	**VMAT**	**p value**
	MEAN±SD	MEAN±SD	
V10	6.52±4.94	5.75±4.62	0.421
V20	4.69±3.88	3.09±3.16	0.066
V30	2.32±2.78	1.38±1.87	0.107
V40	0.74±1.54	0.41±0.85	0.448
V50	0.16±0.61	0.05±0.22	0.613
V60	0.08±0.39	0±0	0.317
V70	0±0.01	0±0	0.317
MEANDOSE(Gy)	10.123±6.37	8.48±5.79	0.164
Dmax (Gy)	37.767±8.75	33.69±9.91	0.093
Integral dose (GyL)	0.2±0.11	0.15±0.07	0.154

All the dosimetric parameters, including V10, V20, V30, V40, V50, V60, and V70 (cc), mean dose (Gy), maximum dose (Gy), and the integral dose (Gy L) to the brainstem, were higher in IMRT plans compared to VMAT plans. However, these differences were not statistically significant.

4. Discussion

A prospective observational study titled "Dosimetric Comparison between Volumetric Modulated Arc Therapy and Intensity Modulated Radiotherapy Treatment Planning Techniques for Head and Neck Cancers" was undertaken in the departments of Radiation Oncology, Mahavir Cancer Sansthan, Patna, and Bihar. The study period was from June 2023 to April 2024.

Radiotherapy plays an important role in the treatment of head and neck cancers. Patients presenting with early-stage disease (stage I or II) generally receive single-modal treatment with either surgery or RT, which leads to similar survival rates. Approximately 60% of patients present with locally or regionally advanced disease, and we generally recommend combined modality therapy, which includes surgery and RT, either with or without chemotherapy, for these patients. Chemoradiotherapy is also the established standard of care for patients with operable disease or patients for whom surgery would result in unacceptable morbidity.Historically, two-dimensional or three-dimensional (CT-based) techniques have treated head and neck cancers. However, since the emergence of IMRT at the turn of the millennium, it has become the de facto standard in the management of head and neck cancers. Main reason for this big shift away from traditional methods is the possibility of protecting healthy tissue and better functional outcomes because of the certainty that IMRT provides, especially in areas like dysphasia and salivary function. The main disadvantage with IMRT is the use of a large number of monitor units and a longer treatment delivery time. The VMAT technique has the ability to produce highly conformal plans in a short duration of time.

This study enrolled a total of 48 patients. We created two plans for each patient, one utilizing the IMRT technique and the other the VMAT technique, ensuring that the baseline characteristics of the two groups—group A (IMRT) and group B (VMAT)—were similar. We delivered a total dose of 70 Gy to the PTV1 and 63 Gy to the PTV2 in 35 fractions, 5 fractions per week, employing a simultaneous integrated boost for each patient using each technique. In my study, the majority of the patients belonged to the age group of 55-65 years, and the median age was 55 years. Stoyanov G.S. et al.

91 found that the median age of diagnosis was 65 years, whereas Massa S.T. et al. 92 found it to be 61.7 years. The maximum incidence of head and neck cancers was in the 40-60 year age group in a study by Alam M.S. et al[1] and in the 50-59 year age group in a study by Mehrotra R. et al.[2], which is comparable to my study.

25% of the patients in my study were female, while 75% were males. Studies have shown that head and neck cancers significantly affect males more than females, with a ratio ranging from 2:1 to 4:1. The male-to-female ratio in the study by Stoyanov G.S. et al.[3] was 3.24:1. In the study by Massa S.T. et al.[4], males constituted 76.7% of the cohort. The male-to-female ratio was 16:1 in the study by Alam M.S. et al. and 3.8:1 in the study by Mehrotra R. et al.

The majority of the patients in this study had a BMI in the normal range, i.e., 18.5 to 24.9 kg/m2. This is in contrast to most studies 95[-103] that have found that people with a BMI <18.5 kg/m^2 experience a higher risk of head and neck cancers compared with people with a normal BMI. When compared to people with a normal BMI, overweight and obese people appear to have a lower risk. Various researchers (104–108) have studied the controversial influence of BMI on the prognosis of head and neck cancers. Out of the four subsites included in my study, the oropharynx was the most frequent subsite of the primary tumor. Larynx was the most common location for head and neck cancers in the study by Stoyanov G.S. et al. The study by Alam M.S. et al. found that carcinoma of the oropharynx and larynx was the most common head and neck cancers in patients over 40 years of age, which is comparable to this study.

In up to 90% of all cases, the histological subtype reported is squamous cell carcinoma, which was the inclusion criteria for my study, and most of the patients had grade II SCC. Approximately 30-40% of the head and neck cancer patients are with early stage disease (stage I or II), while approximately 60% have locally or regionally advanced disease at presentation. Most of the patients in my study had T3 tumours (66.7%). 37.5% had N1 disease, and 33.3% had N2 disease. Thus, the majority of the patients, 62.5%, had clinical stage III disease and 29.2% had stage IVA disease, i.e., locoregionally advanced disease.

4.1. Planning target volume

The two techniques had almost identical target coverage. Various planning studies comparing VMAT with conventional IMRT in different tumor sites have reported that the plans are comparable in terms of PTV coverage, but with a shorter delivery time and fewer MUs in the VMAT plans (Verbakeletal., 2009[5]; Kristoffersen et al., 2009; Korreman et al., 2009[6-7]**.** In my study, I performed treatment planning with 7 fields equidistantly spaced for conventional IMRT, using beam energy of 6MV photons. Planning studies comparing single arc to double arc VMAT plans showed inferiority to double arc plans in terms of conformity, target coverage, dose homogeneity, and OAR sparing (Guckenberger et al., 2009; Bertelsen et al., 2010[8-9]). We used DVH as a planning tool for plan estimation.

In my study, for PTV70Gy, the minimum dose to the PTV, i.e., D98%, was 65.36 Gy (±0.85) for the VMAT group and 65.69 Gy (±0.94) for the VMAT group, and the difference was not statistically significant (p = 0.20). The representative of maximum dose to the PTV, i.e., D_2%, was 72.12 gy (±0.62) for the IMRT group and 72.09 gy (±1.4) for the VMAT group, and this difference was also not statistically significant (p=0.92).Similarly, for PTV63Gy, $D_{98\%}$ was 59.99Gy±1.61 for the IMRT group and 59.27Gy±2.3 for the VMAT group, with the difference being statistically insignificant (p = 0.22), while $D_{2\%}$ was 64.7Gy±1.73 for the IMRT group and 64.7Gy±2.04 for the VMAT group, and here the difference was statistically insignificant too (p = 0.99).

We described dose conformity as CI 95%. The 7-field IMRT group achieved slightly better dose conformity (0.97 ±0.01) than the VMAT group (0.96 ±0.02), but this was not statistically significant (p = 0.29). The in-homogeneity for PTV70Gy was higher for the IMRT group (HI = 0.11±0.0.01) than the VMAT group (HI = 0.09±0.02) and was found to be statistically significant (p = 0.004). Also, the homogeneity index for PTV63Gy was superior in the VMAT group than the IMRT group (0.09±0.04 vs. 0.12±0.03; p = 0.002).

The results of my study bear some similarities to comparative studies conducted in various tumour sites, which demonstrate similar PTV coverage, dose conformity, and homogeneity between the two techniques. However, other studies have reported that double-arc VMAT plans exhibit more homogenous target coverage and better confirmality compared to IMRT plans.

A comparative study by Mashhour et al. in head and neck cancers showed that PTV coverage was similar with both techniques. HI was higher for IMRT plans (0.108±0.021) compared to VMAT plans (0.097±0.017), but this was not statistically significant (p = 0.54). VMAT plans achieved better confirmality than IMRT plans (1.01±0.021 vs. 1.05±0.057; p=0.036).

In head and neck cancers, a study by Kumar SAS et al.[10]; found that target coverage was almost identical between the two techniques. VMAT plans showed superior dose conformity (1.01±0.025) compared to IMRT (1.06±0.068) (p = 0.03). The in homogeneity for PTV boost was higher for IMRT plans (0.107±0.027) compared to VMAT plans (0.095±0.01), but this was not statistically significant (p = 0.43). Also, the HI for PTV elective was 0.094±0.01 for IMRT plans and 0.087±0.005 for VMAT plans, and this difference was not statistically significant either. Crowe et al. did a study of the dosimetric quality of prostate carcinomas in 2013[11], and they found that IMRT and VMAT did not provide significantly different plan quality for prostate carcinoma tumour volumes of the same size. HI was 0.07±0.02 with IMRT plans and 0.06±0.01 with VMAT plans, with a p value of 0.41; the conformity score was better with IMRT plans, i.e., 1.11±0.04, than for VMAT plans, i.e., 1.19±0.13, but was not statistically significant (p = 0.25).Kubicek et al.[12] comparative study on head and neck cancers found no statistically significant differences between IMRT and VMAT plans in terms of dosimetric variables such as PTV coverage, PTV homogeneity, and OAR sparing.

4.2. Monitor Units and Treatment Time

In my study, the average MUs (SD) needed to deliver the dose of 200cGy per fraction were significantly higher for IMRT, i.e., 1651.12±218.43, than for RA technique, i.e., 456.08±48.29 (p<0.001). The calculated treatment time after patient setup was also significantly shorter for VMAT plans (2.99 minutes±0.33) when compared to IMRT plans (7.34 minutes±1.01) (p<0.001). In line with my study's findings, several studies have reported significantly reduced MUs and treatment delivery times with VMAT compared to IMRT. The average MUs in the study by Mashhour et al.[13] were 930.5±142.42 for IMRT plans and 484.25±69.47 for VMAT plans (p = 0.002). The average MUs were 474±80 for RA as against 948±162 for IMRT plans in the study by **Kumar SAS et al.**

4.3. Organs at risk

Spinal cord: In my study, the Dmax to spinal cord PRV was higher with IMRT (49.45Gy±3.5) as compared to the VMAT plan (46.89Gy±3.43), which was statistically significant (p = 0.006). It was also found that VMAT plans had lower values for V10, V20, V30, V40, V40, V50, V60, V70, and Dmean. The differences were statistically significant for V40 (p = 0.048) and V50 (p = 0.007) (3.37±3.36 and 0.11±0.36 vs 6.19±6.18 and 0.86±1.41). These results are similar to the literature. Kumar S.A.S. et al. found that sparing spinal cord in terms of maximum dose was better in the VMAT technique by 4.5% when compared to IMRT. Radha Krishanan et al.[14] showed that spinal cord was better spared by VMAT as compared to IMRT (Dmax 37.2Gy±2.56 vs 40.7Gy±2.3 with p = 0.002).

Brainstem: In my study, VMAT had a lower Dmax to the brainstem than IMRT plans (33.69Gy 9.91 vs 37.77Gy 8.75), but this was not statistically significant (p = 0.09). The parameters V10, V20, V30, V40, V50, V60, V70, Dmean, and integral dose were also lower for VMAT compared to IMRT plans, but the difference was not statistically significant. In line with my research, the brain stem Dmax was reached by Radha Krishnan et al. was also lower for VMAT plans than IMRT plans, with the difference not being statistically significant (46.16 ± 4.55 vs. 49.13 ± 2.1; p = 0.36). In the study by Mashhour et al., the value was higher for IMRT plans as compared to VMAT plans (51.20 ± 9.62 vs. 50.86 ± 8.47, p = 0.046).

Parotid glands: It was difficult to control the parotid mean dose within the tolerance limit due to their involvement in the PTV. The D_{mean} to right parotid gland excluding PTV achieved in my study was lower with VMAT than IMRT plans, but the difference was not statistically significant (24.89 gy±2.55 vs. 25.4Gy±1.55; p = 0.19). The mean to the left parotid gland excluding PTV was also lower with VMAT than IMRT plans, but the difference was not statistically significant (24.8±2.91 vs. 25.34 ± 1.34; p = 0.27).

The IMRT plans had higher V20 (cc) and integral dose to the right parotid gland excluding PTV (7.95 ± 3.91, 25.4 ± 1.55, 1.76 ± 6.66 vs. 7.87±4.15, 24.9±2.56, 0.33±0.16), but this wasn't the case for VMAT plans. Statistically significant (p = 0.571, 0.190, 0.292). This was not statistically significant, though, as the maximum dose (Gy) to the right parotid gland without PTV was slightly lower for IMRT plans compared to VMAT plans (12.78± 6.12 Gy, 4.65± 2.66 Gy, 2.19±1.87 Gy, 0.8±1.17 Gy, 0.16±0.34, 0.00±0.00, 60.97±5.5 vs. 15.13±9.76 Gy, 4.68± 2.39 Gy, 1.14±1.91, 0.43±1.24, 0.03±0.12, 61.09±5.47 Gy; p=0.825, 0.718, 0.942, 0.771, 0.955, 0.976, 0.984, respectively). The integral dose (Gy L) for the left parotid gland without the PTV was higher for IMRT plans than for VMAT plans (25.34±1.34,0.46±0.21vs24.81±2.91,0.34±0.18), but this wasn't statistically significant (p=0.27,0.058, respectively). This was not statistically significant, though, as V10, V20, V30, V40, V50, V60, and V70 (in cc) and the maximum dose to the left parotid gland excluding PTV (Gy) were slightly lower for IMRT plans than for VMAT plans (12.7±5.92, 8.93±3.76, 4.76±2.71, 2.26±2.02, 0.11±0.031, 0±0.004, 62.41±4.58 vs 12.94±5.58, 8.93±3.76, 4.76±2.71, 2.6±2.05, 1.09±1.61, 0.32±1.04, 0.06±0.31, 62.91±4.15).

These results are similar to the literature. The study by Radha Krishnan et al. found that the IMRT plan gave a higher mean dose to the right parotid gland than the VMAT plan (28.2 ± 2.2 vs. 27 ± 2.2), but this difference wasn't huge (p = 0.9). The mean dose to the left parotid gland was also higher for IMRT (29.78 gy±2.62) than VMAT plans (28.1 gy±2), which was also not statistically significant (p = 0.67). The study by Kumar SAS et al. found that the average dose to the right parotid gland, excluding the PTV, was 20.24 ± 2.35 with IMRT plans and 15.95 ± 5.68 with VMAT plans. The p-value was 0.02. The mean dose to the left parotid gland excluding PTV was 20.28 gy±2.58 with IMRT and 18.86 gy±2.9 with VMAT plans, with a p value of 0.03.

5. Conclusion

There are several reasons why volumetric modulated arc therapy (VMAT) may be more effective than intensity modulated radiotherapy (IMRT) in the treatment of early and locally advanced head and neck malignancies. This radiotherapy technique is rapid, secure, and precise. The two techniques yielded comparable PTV coverage. In comparison to IMRT, VMAT designs demonstrated statistically significant improvements in target coverage homogeneity. The dose conformity of IMRT plans was marginally superior to that of VMAT plans; however, this difference was not statistically significant. Compared to IMRT plans, VMAT plans significantly reduced the monitor units and treatment time. We discovered that VMAT outperformed IMRT designs in terms of sparing organs at risk, with a statistically significant difference in the maximal dosage to the PRV spinal cord.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

References

[1] Alam MS et al. Epidemiological profile of head and neck cancer patients in Western Uttar Pradesh and analysis of distributions of risk factors in relation to site of tumor. J Can Res Ther 2020;13:430-5

[2] Mehrotra R et al. Trends of prevalence and pathological spectrum of head and neck cancers in North India. Indian Journal of Cancer 2005;42(2):89-93

[3] Stoyanov GS et al. Demographics of head and neck cancer patients: A single institution experience. Cureus 2017;9(7): e1418

[4] Massa ST et al. Age differences in demographic predictors of head and neck cancer survival. Cancer Epidemiol Biomarkers Prev 2018;27(7), 88

[5] Verbakel et al. Volumetric intensity-modulated arc therapy vs. conventional IMRT in head and neck cancer: a comparative planning and dosimetric study. Int J Radiat Oncol Biol. Phys. 2009;74(1):252:259

[6] Kristoffersen et al. Rapid Arc volumetric modulated therapy planning for prostate cancer patients. ActaOncologica. 2009;48(2):227-232

[7] Korreman et al. Dosimetric verification of RapidArc treatment delivery. ActaOncologica. 2009;48(2):185-191

[8] Guckenberger et al. Is a single arc sufficient in volumetric modulated arc therapy (VMAT) for complex shaped target volumes? RadiotherOncol. 2009; 93(2):259-65

[9] Bertelsen et al. Single arc volumetric modulated arc therapy of head and neck cancer. RadiotherOncol. 2010;95(2):142-8

[10] S.A. Syam Kumar, NagarajanVivekanandan, PadmanabanSriram. A study on conventional IMRT and RapidArc treatment planning techniques for head and neck cancers. Rep Pract Oncol Radiother. 2012;17(3):168-175

[11] Crowe et al. Retrospective evaluation of dosimetric quality for prostate carcinomas treated with 3D conformal, intensity modulated and volumetric modulated arc radiotherapy. J Med Radiat Sci. 2013;60(4):131-138

[12] Kubicek, GJ et al. Intensity modulated radiation therapy versus RapidArc in the treatment of head and neck cancer. Int J Radiat Oncol Biol. Phys. 2011;81(2):245-238

[13] Karim Mashhour et al. RapidArc vs conventional IMRT for head and neck cancer: is faster necessarily better? Asian Pac J Cancer Prev 2018;19(1):207- 211

[14] Krishnan Jayapalan et al. Comparison of rapid arc and intensity modulated radiotherapy plans using unified Dosimetry index and the impact of conformity index on unified dosimetry index evaluation 2017;42(1):14-17