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RESEARCH ARTICLE

A COMPARATIVE PLANNING AND DOSIMETRIC STUDY COMPARING VOLUMETRIC MODULATED ARC THERAPY (VMAT) VS DYNAMIC INTENSITY-MODULATED RADIATION THERAPY (IMRT) IN HEAD AND NECK CARCINOMAS

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ABSTRACT

Background: Introduction of IMRT techniques for the treatment of Head and Neck carcinomas (HNSCC) has given better dose conformity and sparing of the organs at risk (OARs). Disadvantage of fixed angle IMRT is longer radiation delivery time and increased patient exposure to low dose radiation. Recently, VMAT has been developed which enables IMRT-like dose distributions to be delivered using a single rotation of the gantry and thereby reducing the treatment time.
This study is undertaken to compare VMAT (single and double arcs) and IMRT plans for dose homogeneity, dose conformity and ability to spare OARs in HNSCC.
Aims and objectives:

- To compare IMRT and VMAT (Single and double arc) techniques in terms of tumor coverage, conformity and doses received by normaltissues.
- To compare the treatment delivery time between IMRT and VMAT (single arc and double arc) in terms of monitor units(MUs).

Methods and Materials: Between January 2014 to December 2015, 43 patients with nasopharyngeal, oropharyngeal, hypoharyngeal and laryngeal cancers were taken. IMRT, VMAT single arc and VMAT double arc plans were generated. Comparison of doses using dose volume histogram (DVH) was done. Doses to normal structures, tumor coverage and dose homogeneity and dose conformity was compared. **Results:** VMAT double arc plans had a superior homogeneity index(HI) equal to (0.1 ± 0.01) [p = 0.001] and best conformity(CI95%=1.2±0.16)[p= 0.02] compared to single arc plans with a HI of (0.1 ± 0.02) and slightly inferior conformity(CI95% = 1.3 ± 0.17) and IMRT plans with a HI of (0.1 ± 0.16) and least conformity (CI95%= 1.3 ±0.23). The average MU needed to deliver the dose of 225cGy per fraction was (637 ± 117.6 MU) [0.001] and (600.7 ± 113.95 MU) for double arc and single arc as against (1121.7 ± 390.27 MU) for the IMRT plan. The average number of monitor units was reduced by 53% for VAMT plans and double arc plans required only 10% more monitor units than single arc plans. **Interpretation and Conclusion:** VMAT double arc proved a significant sparing of OARs without compromising target coverage compared to IMRT. Hence VMAT is a fast, safe and a better treatment option in our comparison for HNSCC that uses lower MUs compared to IMRT.

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INTRODUCTION

Head and neck squamous cell carcinoma (HNSCC) is the fourth most common neoplasm worldwide with an estimated annual global incidence of more than 500,000 cases diagnosed (Joshi, 1989). It is one of the ten leading causes of cancer in India, according to population based cancer registry accounting for 23% of all cancer in males and 6% in females (National cancer registry programme, 2001).

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Patients with HNSCC are at considerable risk of mortality with more than 300,000 deaths yearly attributable to the disease (White, 2013). Head and neck cancers arise from mucous lining of respiratory, digestive tracts, salivary glands, and lymph nodes. They are histologically heterogeneous and organs at risk have less tolerance to radiation. Radiation therapy is a mainstay of treatment for both early and advanced stage head and neck cancer. Treatment planning for advanced head and neck cancer is a knotty problem due to the complex shape of target volumes and the need to spare critical organs like the mandible, parotid glands, brainstem, spinal cord, and other normal structures.

These organs often lie very close to the target volumes which commonly have an irregular concave shape. Due to the close proximity of tumor to critical structures, head and neck cancer presents a challenge for radiotherapy (Syam Kumar, 2012). Often better sparing of one OAR implies sacrificing another OAR, and in most patients high-grade radiation-induced toxicity is unavoidable while ensuring sufficient dose coverage of the planning target volume (PTV). This may result in severe consequences for the quality of life of these patients (Verbakel, 2009). Treatment with radiotherapy is curative for many patients with localized disease, but with current radiation techniques, dose is limited by both acute and late side effects and the anatomy of the head and neck region which is very complex, with bony structures, soft tissues and air cavities. The lack of tumor motion due to breathing makes patient set up easy and can be reproduced accurately (Syam Kumar, 2012). Traditional head and neck conformal radiation therapy, in addition to problems related to matching of multiple beams, was often associated with multiple toxicities including xerostomia, dysgeusia, hearing loss, brain necrosis, osteonecrosis of the mandible.

To minimize the difficulties of matching multiple beams and ameliorate toxicities, radiation therapy for most head and neck cancer has shifted away from traditional conformal techniques (3DCRT) to fixed-angle intensity modulated radiation therapy (IMRT). IMRT uses multiple intensity-modulated beams to deliver non-uniform dose to the target. Beam modulation is created using a multileaf collimator (MLC). Superimposing numerous small beams produces a dose distribution with better target dose conformity and better sparing of critical structures than 3DCRT. IMRT allows the ability to escalate the target volume dose while reducing the dose to surrounding normal tissue and sparing organs at risk (OAR). Disadvantages of fixed angle IMRT compared to conformal therapy include: longer radiation delivery time and increased patient exposure to low dose radiation. IMRT can sculpt precise dose distribution in three dimensions. IMRT presents more conformity for irregular target volumes in the vicinity of critical organs and provides better tumor control and reduces dose to normal structures. The main disadvantage of IMRT, in spite of its efficiency in dose conformity to tumor, is increased treatment delivery time and increased monitor units (MUs). Besides, dose escalation becomes possible, which can potentially improve local tumor control. For each daily fraction, IMRT can give higher dose to the gross tumor volume, resulting in a more effective biological dose (Fung-Kee-Fung, 2012).

Recently, a new version of IMRT, volumetric modulated arc therapy (VMAT) has been developed. In VMAT, instead of using multiple fixed fields, the radiation is delivered in a continuous arc as the linear accelerator rotates around the patient, while the beam is modulated via the MLC, variable dose rate and variable gantry speed. Early reports suggest that VMAT produces dose-distributions comparable to IMRT for a variety of treatment site. The principle of simple conformal arc therapy is to spread the entrance dose shaped to the projected tumor outline over many angles. The rotational centre is in the tumor so that the high dose is focused there with a steep fall-off outside the tumor. VMAT consists of a single arc or multiple arcs modulated technique which was released for clinical use in April2008. In VMAT, multileaf collimator (MLC) positions, dose rates and gantry speeds can be dynamically varied during the delivery of radiation over one arc, typically taking 70–90 seconds. VMAT enables IMRT-like dose distributions to be delivered using a single rotation or multiple rotations of the gantry. VMAT aims to achieve several objectives at once: (i) improve OARs sparing compared to other IMRT solutions; (ii) maintain or improve the same degree of target coverage; (iii) reduce significantly the treatment time (beam on time) per fraction (Fung-Kee-Fung, 2012). This study is undertaken to compare VMAT (single and double arcs) and IMRT plans for dose homogeneity, dose conformity and ability to spare OARs in HNSCC. As VMAT is a novel approach and very few studies investigating its role in the treatment of head and neck cancers have been done, this study would explore the possible advantage of the new technique.

AIMS AND OBJECTIVES

- To compare IMRT and VMAT (single arc and double arc) techniques in terms of tumor coverage, conformity and doses received by normal tissues.
- To compare the treatment delivery time between IMRT and VMAT techniques in terms of MUs.

MATERIALS AND METHODS

Source of data: The sources of data for the dissertation are patients presenting with carcinoma nasopharynx, oropharynx, hypopharynx and larynx at Department of Radiation Oncology, Vydehi Institute of Medical Sciences, Bangalore. Duration of study – Jan 2015 to Dec 2015

Sample Size: The Sample size has been estimated in consultation with a biostatistician. The sample size chosen is 43. This was estimated based on data obtained from the study done by Syam Kumar SA et al. with a power of 80% and alpha 5% for calculation of homogeneity index (HI), based on difference of mean. Method of collection of data (including sampling, procedure, if any): 43 patients with nasopharyngeal, oropharyngeal, hypopharyngeal and laryngeal cancers were included in this study. Appropriate investigations were done.

Inclusion criteria

- Age 18 to 65years
- Performance Status-0-2 (ECOGCriteria).
- Patients who were considered suitable for curative treatment with definitive radiotherapy ± chemotherapy with head and neck cancers (Nasopharynx, oropharynx, Hypopharynx and larynx)

Exclusion criteria

- Metastaticdisease.
- ECOG Performance status more than2
- Post-operativecases.
- Previous irradiation to head and neckarea.

Informed written consent of the patient: When all the investigations were within the normal limits, patient's written consent was taken after explaining the nature of the disease, its treatment options, duration of treatment and side effects in the own vernacular language. Patients were also explained about the clinical trial in depth and also that it is dosimetric study and they would be treated as per the standard protocol.

TREATMENT PLAN SCHEME

CT SIMULATION

Immobilization: The patients were immobilized using thermoplastic cast and carbon fiber base plate. The patient was kept in supine position and appropriate head rest was chosen. The shoulders were pulled down as far as possible using shoulder retractor.

Simulation: Fiducial markers were kept to define the reference point. 2.5 mm CT axial cuts of the patient were acquired. The area of interest was defined based on the site. The CT images were exported to 3D – Eclipse planning system in DICOM format.

Contouring: This is one of the most important aspects in IMRT treatment planning. We have followed the recommendations of ICRU 50 and its supplement ICRU 83. At first the gross tumor volume (GTV) was delineated. It includes both primary and nodal tumor volumes. Then the clinical target volume was contoured depending on the stage and site of the disease. In SIB-IMRT and VMAT, we have different clinical target volumes. They are named CTV 1, CTV 2 and CTV 3.

- CTV 1 is gross tumor (primary and enlarged nodes) with margins based on clinical and radiologic justification.
- CTV 2 encompases soft tissue and nodal regions adjacent to CTV 1. It includes generally ipsilateral adjacent lymph nodes which harbours high risk sub clinical disease.
- CTV 3 includes elective nodal regions constituting ipsilateral, contra lateral and retropharyngeal lymph nodes which contain low risk sub clinical disease.

After delineation of CTV, the PTV was generated. The PTV is planning target volume which includes entire CTV with margins. The margin is given for inter and intra fraction setup errors, penumbra and internal motion. The margin should be added to allow for uncertainties related to movement of the tumor volume from treatment to treatment and for potential intra fraction organ motion. The size of the margin depends on the particular treatment site and the specific treatment technique used, especially the immobilization and localization techniques. In our institutes we have usedamarginof5mmaroundtheCTV.Therefore,wenowhavethree PTVs,i.e. PTV 1, PTV 2 and PTV 3 which are generated from CTV 1, CTV 2 and CTV 3 respectively. Then, the surrounding critical structures were delineated. DVHs were generated for PTVs and the normal structures.

Treatment planning system: All IMRT plans and VMAT plans were optimized on the Eclipse Treatment Planning System version 11. The optimization software allows users to adjust all the optimization criteria (dose constraints and priorities) interactively during optimization in order to achieve an optimal treatment plan.

Imrt Planning Technique: IMRT plans were generated with five to seven coplanar fields using an isocentric technique using 6MV energy. The fluence of each modulated field was optimized by inverse planning software. The fluence for each radiation beam was generated by sliding window technique based on 120 MLCs of 0.5 and 1 cm leaf-width at the iso-center. Volumetric doses were calculated using the Anisotropic Analytical Algorithm (AAA, version 8.6) with a dose calculation grid of 2.5 mm.

Vmat Single and double arc planning technique: VMAT single arc plans were generated using one coplanar arc 360o (clockwise from 181o to 179o) and double arc plans using complementary coplanar arcs of 360o (one counter-clockwise from 179o to 181o, one clockwise from 181o to 179o). The optimization was based on the Progressive Resolution Optimization (PRO) algorithm.

The iterative inverse planning process aimed to simultaneously optimize the instantaneous MLC positions, the dose rates and the gantry rotation speeds to achieve the desired dose distributions, beginning with coarse gantry sampling. As the optimization progressed, the arc resolution was gradually improved. The purpose was to reduce the optimization time by using small control points first and progressively enhancing the number of control points to achieve precise dose distributions. After optimization, the dose was calculated using AAA, version 8.6 with a dose calculation grid of 2.5 mm.

Planning Objectives: Both VAMT plans and IMRT plans utilized simultaneous integrated boost (SIB) approaches with targets of PTV 1, PTV 2 and PTV 3, being prescribed with 67.5 Gy, 60 Gy and 54 Gy, respectively. Each plan was normalized to an isodose level such that the coverage of multiple targets could meet the acceptance criteria. According to the Radiation Therapy Oncology Group (RTOG), the planning objectives for targets were:

- More than 95% of the target volume received the prescriptiondose;
- Less than 20% of the target volume received more than 110% of the prescriptiondose;
- Less than 1% of the target volume received less than 93% of the prescription dose; and
- Less than 5% of the target volume received more than 80Gy.

The acceptance criteria for OARs used as the guidelines in defining planning objectives are shown in Table 6.

Table 1. Treatment planning objectives

STRUCTURE	PARAMETER	OBJECTIVE
PTV 1	Prescribed dose	67.5 Gy
PTV 2	Prescribed dose	60 Gy
PTV 3	Prescribed dose	54 Gy
Brain stem	Dmax	<54 Gy
Spinal cord	Dmax	<45 Gy
Parotids	Dmean	<26 Gy
Larynx	Dmean	<45 Gy
Inferior constrictor	Dmean	<45 Gy
Mandible	Dmax	< 70 Gy

Besides the dose and dose-volume parameters in the dose constraints, the priority setting of different targets and structures are also an important parameter to achieve an optimal plan. For instance, high priorities should be given to critical structures and target volumes to ensure the dose limits of these critical structures are not exceeded and the dose coverage of the targets is adequate.

Evaluation of Plans

Target PTVs: Target PTVs were compared in both plans using dose homogeneity and conformity indices.

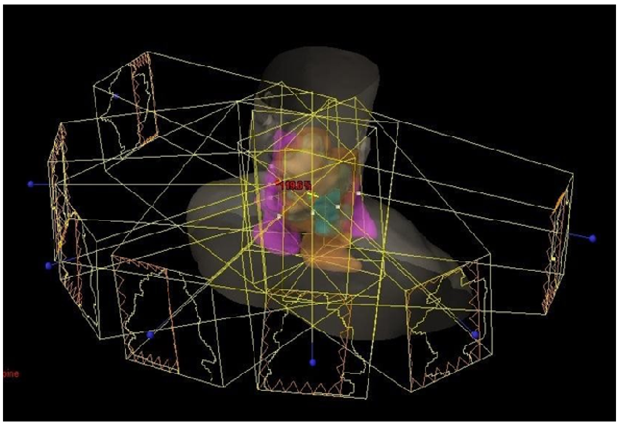

Fig 1. Field arrangement in IMRT

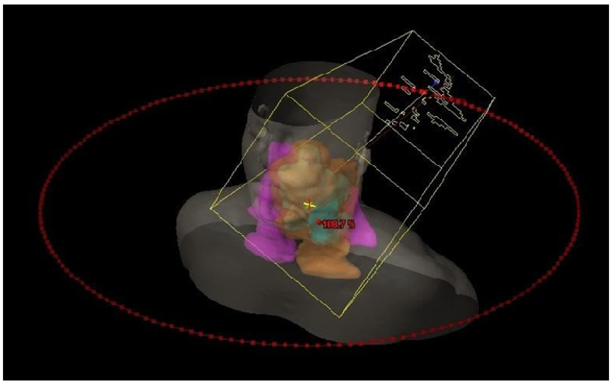

Fig 2. Field arrangement in VMAT singlearc

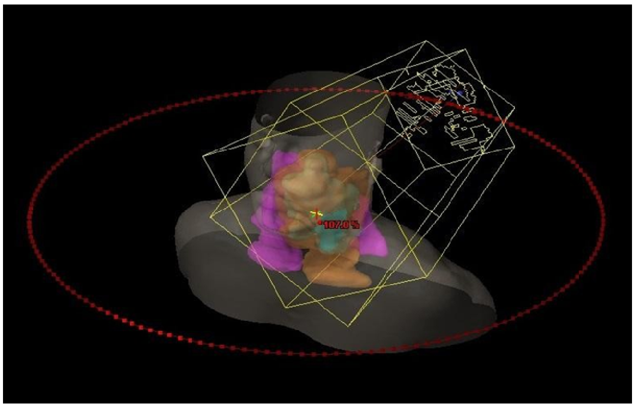

Fig 3. Field arrangement in VMAT singlearc

Homogeneity index: The dose homogeneity was expressed in terms D2% – D98% difference (difference between the dose received by 2% and 98% volume of the PTV) divided by D50% (Dose received by 50% volume of PTV). The dose homogeneity was calculated for PTV67.5.

Conformity index: The degree of conformity of the plans was measured with a Conformity Index, CI95%. This was defined as the ratio between the patient volume receiving at least 95% of the prescribed dose and the volume of the PTV. The CI95% of each PTV was found andanalyzed.

OARS: For OARs, the analysis included the maximum dose to the brainstem, spinal cord, optic apparatus, temporal lobe and mandible. Whereas for parotid glands, submandibular glands, larynx, inferior constrictor and cochlea mean dose was analyzed.

Number of mus: The number of MUs used between IMRT plans and VMAT with single and double arcs were recorded and compared. The plans were used for dosimetric comparison and were treated with standard institute protocol

Statistical analysis

Statistical Methods: The quantitative data comparison was done using ANOVA test. P-value less than or equal to 0.05 was considered statistically significant.

Statistical software: Data analysis: data were analyzed using Microsoft XL for windows. Microsoft word, Apple Pages and Excel have been used to generate graphs, tables etc.

RESULTS

A total number of 43 patients with nasopharyngeal, oropharyngeal, hypopharyngeal and laryngeal cancers were recruited from January 2014 to Dec 2015 for this study.

Table 2. Patient characteristics

Patient characteristics	Number of patients	Percentage (%)
Gender		
Male	40	93
Female	3	7
Age range in years		
18-49	18	42
50-59	14	32
60	11	26
Primary site		
Nasopharynx	6	14
Oropharynx	13	30
Hypopharynx	8	19
Larynx	16	37
T Stage		
T1	10	23
T2	11	26
T3	14	33
T4/T4a	7	16
T4b	1	2
N Stage		
N0	13	30
N1	9	21
N2	17	40
N3	4	9
Group Staging		
Stage I	6	14
Stage II	5	12
Stage III	11	26
Stage IV	21	48

The patients were selected according to the inclusion and exclusion criteria as mentioned earlier. IMRT, VMAT single arc and VMAT double arc plans were done depending on each of the patients' planning CT. In the present study of forty three of head and neck cancers, the various characteristics are shown in the table 2. VMAT with double arc showed superior homogeneity and conformity compared to single arc plans and IMRT

DISCUSSION

Treatment planning for head and neck cancer is a tricky situation due to the complex shape of target volumes and the need to spare critical organs like the mandible, parotid glands, brainstem, spinal cord and other normal structures. Due to the close proximity of tumor to critical structures, head and neck cancer presents a challenge for radiotherapy.

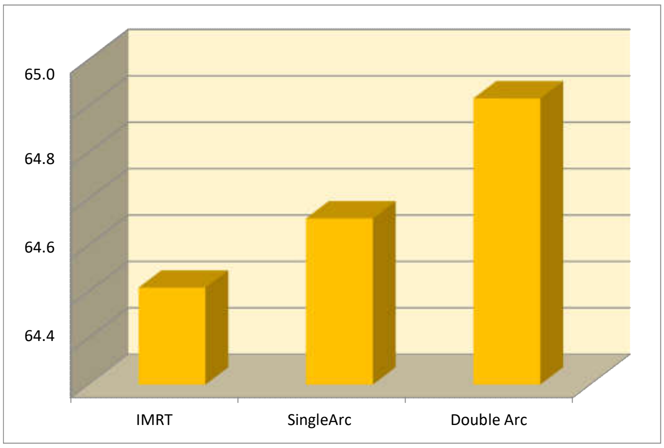

Fig. 4. Bar graph comparing dose received by 98% of volume in the 3 modalities

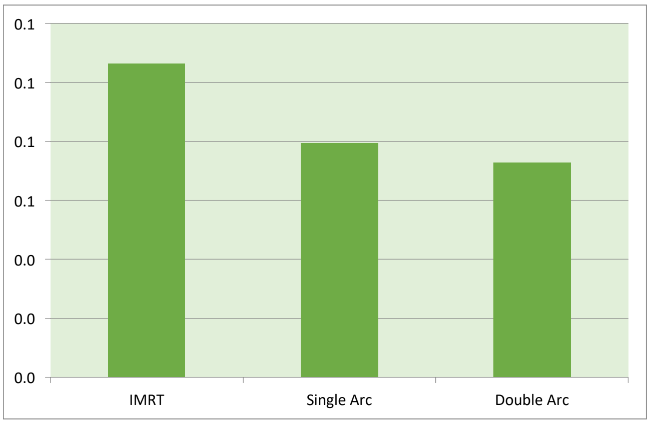

Fig 5. Bar graph showing homogeneity index in both modalities

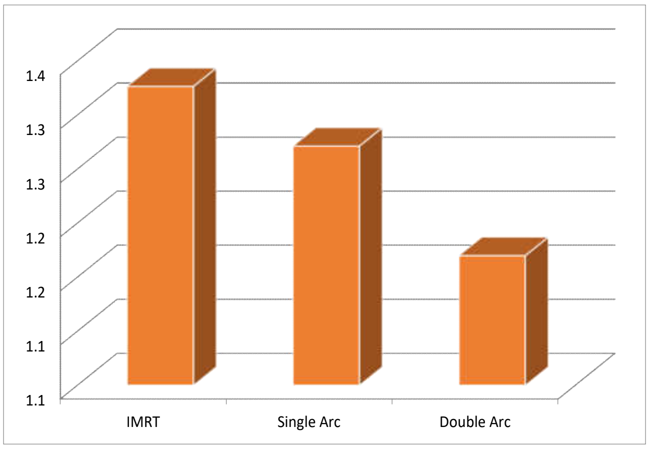

Fig 6. Bar graph showing conformity index in both modalities

Treatment with radiotherapy is curative for many patients with localized disease, but with current radiation techniques, dose is limited by both acute and late side effects and the anatomy of the head and neck region which is very complex, with bony structures, soft tissues and aircavities (Syam Kumar, 2012; Verbakel, 2009). Introduction of IMRT techniques for the treatment of HNSCC has given better dose conformity and sparing of the organs at risk (OARs). Disadvantage of fixed angle IMRT is longer radiation delivery time and increased patient exposure to low dose radiation. Recently, VMAT has been developed which enables IMRT-like dose distributions to be delivered using a single rotation of the gantry (White, 2013). In this, the gantry speed and the dose rate vary continuously during delivery which is enabled by continuous beam modulation brought about via the continuous adjustments of the multi-leaf collimators. Compared to static-beam IMRT, rotational VMAT decreases treatment delivery time giving better patient comfort, compliance and decreased intra-fractional movements (Fung-Kee-Fung, 2012). The design and choice of our radiotherapy protocol was based on results of a study done by Syam Kumar et al. (2012). A total of 43 patients with nasopharyngeal, oropharyngeal, hypopharyngeal and laryngeal cancers were enrolled for our study. Three PTV volumes were delineated for high, intermediate risk and low risk. Then, the surrounding critical structures were delineated. SIB-IMRT, SIB-VMAT single arc and SIB-VAMT double arc plans were generated on each of the patients planning CT scan. All the treatment plans were evaluated using dose volume histogram (DVH). $PTV_{67.5Gy}$ volumes for all the 43 cases ranged from 104.26 cm^3 to 282.64 cm^3. VMAT double arc had a better target coverage [D 98% = 64.0 ± 0.91 Gy (p = 0.0001)],D2%=69.9±0.59(p=0.001)], than VMAT singlearc [D98%=64.3± 0.78,D2%=70.1±0.42] and IMRT plans [D98%=64.8±1.08,D2%=70.1± 0.67]. This was in contrast to Syam Kumar et al. (2012) where no difference was found with respect to the target coverage. Double arc plans had a superior homogeneity index equal to (0.1 ± 0.01) [p = 0.001] compared to single arc plans with a HI of (0.1 ± 0.02) and IMRT plans with a HI of (0.1 ± 0.16). This was consistent with the findings of Syam Kumar et al. (2012) and Verbakel et al. (2013) Whereas Fung-Kee-Fung et al. (2012) and White et al. (2013) reported no difference in VMAT or IMRT with respect to homogeneity. VMAT using double arc plans achieved the best conformity (CI95% = 1.2 ± 0.16) [p = 0.02] while VAMT using single arc (CI95% = 1.3 ± 0.17) was slightly inferior to VAMT with double arc but superior to IMRT plan (CI95% = 1.3 ±0.23).

Syam Kumar et al. (2012) reported best conformity of double arc plans (CI95% = 1.03 ± 0.025) compared to IMRT plans (CI95% = 1.06 ± 0.068) with a p value of 0.03. But there was no statistically significant difference between single arc and double arc plans or IMRT and single arcplans. The average MU (±SD) needed to deliver the dose of 225cGy per fraction was (637 ± 117.6 MU) [p = 0.001] for double arc, (600.7 ± 113.95 MU) for single arc as against (1121.7 ± 390.27 MU) for the IMRT plan. The average number of monitor units was reduced by 53% for VAMT plans and double arc plans required only 10% more monitor units than single arc plans. Verbakel et al.[6] found that average number of monitor units was reduced by 59% for the VMAT plans, and a two-arc plan required only 5% more monitor units than a single-arc plan. When it comes to OAR sparing, double arc showed a better sparing of spinal cord in terms of maximum dose (31.6 ± 6.43 Gy) [p = 0.001] compared to single arc (33.2 ± 7.66 Gy) and IMRT (37.0 ± 6.23 Gy). Sparing of brain stem was better in double arc (28.6 ± 15.16) compared to single arc (29.3 ± 15.11) and IMRT (32.1 ± 16.37) though not statistically significant [p = 0.5]. Mandible received less dose in double arc plan (58.3 ± 14.29 Gy) compared to single arc (60.3 ± 13.49 Gy) and IMRT (63.6 ± 12.85 Gy) [p =0.1]. Mean parotid dose to the ipsilateral parotid in IMRT was higher (35.64 ± 4.09 Gy) compared to VMAT single (33.49 ± 5) and VMAT double arc (32.41 ± 4.89 Gy) [p = 0.2]. Whereas the mean parotid dose to the contra lateral parotid was reduced significantly in VMAT double arc (25.42 ± 2.4) [p = 0.017] compared to single arc (26.34 ± 1.8) and IMRT plans (27.81 ± 1.5).

Table 3. Dosimetric results for the PTV (67.5 Gy volume) comparing IMRT, VMAT single arc and VMAT double ARC

PARAMETER	IMRT	VMAT SINGLE ARC	VMAT DOUBLE ARC	p value
	Mean ± SD	Mean ± SD	Mean ± SD	
D 98% (Gy)	64.0 ± 0.91	64.3± 0.78	64.8 ± 1.08	0.0001
D 2% (Gy)	69.9± 0.59	70.1 ± 0.42	70.1 ± 0.67	0.001
D 50% (Gy)	67.5 ± 0.56	67.7± 0.68	67.9± 0.70	0.019
HI	0.10 ± 0.16	0.10 ± 0.02	0.1± 0.01	0.001
CI 95%	1.30 ± 0.23	1.30± 0.17	1.20 ± 0.16	0.02
MU s	1121.7 ± 390.3	600.7 ± 113.9	637.0 ± 117.6	0.001

Table 4. Dose received by the OARs by different techniques

PARAMETER	IMRT	VMAT SINGLE ARC	VMAT DOUBLE ARC	p value
	Mean ± SD	Mean ± SD	Mean ± SD	
Dmax Brain Stem	32.1 ± 16.37	29.3 ± 15.11	28.6 ± 15.16	0.5
Dmax Spinal Cord	37 ± 6.23	33.32 ± 7.66	31.6 ± 6.43	0.001
Dmean Parotid	25.35 ± 12.03	23.65 ± 11.3	22.9 ± 11.8	0.6
Dmean Ipsilateral parotid	35.64 ± 4.09	33.49 ± 5	32.41 ± 4.89	0.2
Dmean Contralateral parotid	27.81 ± 1.5	26.34 ± 1.8	25.42 ± 2.4	0.17
Dmax Mandible	63.6 ± 12.85	60.3 ± 13.49	58.3 ± 14.29	0.1

No significant difference was seen with respect to sparing of inferior constrictor between the 3 plans i.e. mean dose received by inferior constrictor in VAMT double arc was (57 ± 7.68 Gy), VMAT single arc was (57.6 ± 8.36 Gy) and IMRT was (57.8 ± 7.68 Gy) [p = 0.88]. Similarlyno difference was seen in the mean dose received by the larynx between IMRT (54.4 ± 12.51Gy), VMAT single arc (53.7 ± 12.68 Gy) and VMAT double arc (51.3 ± 13.49) [p = 0.55]. When compared to IMRT, VAMT using double arc proved to have superior dose homogeneity in PTV. Also, VAMT double arc plan showed improvements in organs at risk and healthy tissue sparing without compromising target coverage. Unlike in IMRT, optimization can be paused at each resolution level in VMAT, which will ensure additional time for the optimization to attain saturation. This shows slight improvement in the final dose distribution. The main disadvantage of IMRT is the higher number of MUs and resulting longer treatment time. Such prolonged treatment fraction delivery times (greater than 15 min.) may have significant impact on IMRT treatment outcome, especially for tumors with a low alpha/beta ratio and a short repair halftime. VMAT treatment is delivered rapidly, which has the advantage of decreasing the risk of intra-fractional positional shifts of the patient and results in better patient comfort and compliance. VMAT requires only 40% of the number of MUs compared with the IMRT techniques. VMAT plans were the fastest treatment option of modulated approaches in this comparison. Dose to healthy organs not in the proximity of the PTV arises largely from collimator transmission and scatter radiation from the LINAC, and this dose is proportional to the number of MUs. Such scattered doses can increase the risk of secondary tumors. Such a risk is now largely reduced by the use of VMAT without concessions to the dose distribution. Among VMAT plans, double arc plan, which involves two full gantry rotations, offers a greater freedom in dose modulation. The sum of two arcs reduces hot spots in the PTV where the second arc compensates for areas of suboptimal dose (Syam Kumar, 2012). A second possible explanation for the advantage of using two arcs is a physical limit to dose homogeneity for a single arc arising from limited leaf speed and the limited number of control points. With use of a single arc, the leaves can move with a maximum speed of 0.5 cm per degree of gantry rotation, whereas optimal coverage of the PTV at specific gantry positions could require dose delivery at two or more separated parts of the PTV along one leaf pair. Because the head-and-neck plans studies contained large PTVs, the span of the entire PTV over a leaf pair can easily be 15 cm. If a part of the PTV has to be blocked at one gantry position, it can take 20^{o} of gantry rotation or more before the leaf has travelled to the other side of the PTV. Also, a second arc adds more freedom for possible leaf positions. Each VMAT plan required only a single optimization session and the same number of optimization steps, independent of the amount of interactive change of the optimization objectives. It is obvious that sliding window IMRT can be planned in a much shorter period of time as compared to VMAT, but VMAT has the lowest estimated treatment delivery time. Also with respect to plan quality, VMAT can meet the most dose–volume criteria (White, 2013).

Conclusion

Our study demonstrated that, in the treatment planning of head and neck cancers, VMAT double arc plans:

- Gave superior, target coverage, homogeneity and dose conformity when compared with IMRT plans and VMAT single arcplans.
- Demonstrated a significant improvement in dose reduction to brainstem, spinal cord andparotids.
- Allows for large reductions in the number of MUs and treatment delivery times.

Since the VMAT double arc technique is effective in producing clinically acceptable plans, with added advantage of better sparing OARs, thereof it may be more beneficial for head and neck cancers treatments thanIMRT.

REFERENCES

Agarwal JP., Nemade B., Murthy V., Ghosh Laskar S., Budrrukar A., Gupta T. et al., 2008. Hypofractionated, palliative radiotherapy for advanced head and neck cancer. RadiotherOncol Oct;89(1):51-6.

Benghiat, H., Sanghera, P., Cashmore, J., Hodson, J., Mehanna, H. 2014. Four Week Hypofractionated Accelerated Intensity Modulated Radiotherapy and Synchronous Carboplatin or

Cetuximab in Biologically Staged Oropharyngeal carcinoma; Cancer and clinical oncology Volume 3No2.

Clivio A., Fogliata A., Franzetti-Pellanda A. et al., 2009. Volumetric-modulated arc radiotherapy for carcinomas of the anal canal: a treatment planning comparison with fixed field IMRT. *Radiother Oncol*., 92:118–24.

Cozzi L., Dinshaw KA., Shrivastava SK. et al., 2008. A treatment planning study comparing volumetric arc modulation with Rapid Arc and fixed field IMRT for cervix uteri radiotherapy. *Radiother Oncol.,* 89:180–91.

Fogliata A., Clivio A., Nicolini G., Vanetti E., Cozzi L. 2008. Intensity modulation with photons for benign intracranial tumours. A planning comparison of volumetric single arc, helical arc and fixed gantry techniques. RadiotherOncol [epub].

Fogliata A., Nicolini G., Vanetti E. et al. 2006. Dosimetric validation of the anisotropic analytical algorithm for photon dose calculation: fundamental characterization in water. *Phys Med Biol.,* 51:1421–38.

Fung-Kee-Fung SD., Hackett R., Hales L. et al., 2012. A prospective trial of volumetric arc therapy vs conventional intensity modulated radiation therapy in advanced head and neck cancer. *World J Clin Oncol.,* 3(4): 57-62.

Golen M., Skladowski K., Wygoda1 A., et al., 2005. A comparison of two scoring systems for late radiation toxicity in patients after radiotherapy for head and neck cancer. *Rep Pract Oncol Radiother*., 10(4):179–92.

Gregoire V., Eisbruch A., Hamoir M. et al., 2006. Proposal for the delineation of the nodal CTV in the node-positive and post-operative neck. *Radiother Oncol.,* 79:15–20.

Gregoire V., Levendag P., Ang KK. et al., 2003. CT based delineation of lymph node levels and related CTVs in the node-negative neck: Dahanca, Eortc, Gortec, Ncic, RTOG consensus guidelines. *Radiother Oncol*., 69:227–36.

Hall EJ, Phil D. 2006. Intensity-modulated radiation therapy, protons, and the risk of second cancers. *Int J Radiat Onc Biol Phys*., 65:1–7.

Holt A., Gestel DV., Arends MP. et al., 2013. Multi-institutional comparison of volumetric modulated arc therapy vs. intensity-modulated radiation therapy for head and neck cancer: a planning study. *Radiat Oncol*., 8:26-37.

Joshi, Sanghvi, Rao et al., 1989. Epidemiology of head and neck cancer. *Seminar in surgical Oncology.,*5(5):305-09.

Karl Otto. Volumetric modulated arc therapy: IMRT in a single arc. Med Phy 2008;35:310–7.

Kipiran D., Jarzabski, Pawlowska B. Michalski W., Kawecki A. 2011. SIB-IMRT radiotherapy given concomitantly with cisplatin for locally advanced squamous cell head and neck cancer (SCHNC). Evaluation of the early results and toxicity; Otolaryngol Pol sep;65(5 Suppl):117-125.

Kubes J., Cvek J., VondracekV., Pala M., Felt D. 2011. Accelerated radiotherapy with concomitant boost technique (69.5 Gy/5 weeks) an alternative in the treatment of locally advanced head and neck cancer; Strahlenther Onkol. Oct;187(10):651-5.

Lee N., Puri D., Blanco AI., Chao KS. 2007. Intensity modulated radiation therapy in head and neck cancers: an update. Head Neck., 29:387–400.

National cancer registry programme, consolidated report of the population based cancer registries. 1990-1996. Indian council of medical research. New Delhi - 2001.

Popovtzer A., Eisbruch A. 2008. Advances in radiation therapy of head and neck cancer. *Expert Rev Anticancer Ther*., 8:633–44.

Porceddu S.V., Rosser B., Burmeister B.H., Jones M., Hickey B., Baumann K., Gogna K Hypofractionated radiotherapy for the palliation of advanced head and neck cancer in patients unsuitable for curative treatment - "Hypo Trial" RadiotherOncol 2007 Dec;85(3):456-62.

Slosarek K, Szlag M, Bekman B, Grzadziel A. 2010. EPID in vivo dosimetry in Rapid Arc technique. *Rep Pract Oncol Radiother.,* 15(1):8–14.

Sukumar P., Padmanaban S., Jeevanandam P., Syam Kumar SA., Nagarajan V. 2011. A study on dosimetric properties of electronic portal imaging device and its use as a quality assurance tool in volumetric modulated arc therapy. *Rep Pract Oncol Radiother.,* 16(6):248–55.

Syam Kumar SA., Vivekanandan, Sriram P. et al., 2012. A study on conventional IMRT and RapidArc treatment planning techniques for head and neck cancers. *Rep Pract Oncol Radiother.,* 17: 168-175.

Van Esch A., Tillikainen L., Pyykkonen J. et al., 2006. Testing of the analytical anisotropic algorithm for photon dose calculation. *Med Phys*., 33:4130–48.

Vanetti E., Clivio A., Nicolini G. et al., 2009. Volumetric modulated arc radiotherapy for carcinomas of the oro-pharynx, hypo-pharynx and larynx: A treatment planning comparison with fixed field IMRT. *Radiother Oncol.,* 92:111-117.

Verbakel WFAR., Cuijpers JP., Hoffmans D. et al., 2009. 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.,* 74(1): 252-259.

Vosmik M., Kordac P., Paluska P. et al., 2008. IMRT using simultaneous integrated boost (66 Gy in 6 weeks) with and without concurrent chemotherapy in head and neck cancer—toxicity evaluation. *Rep Pract Oncol Radiother.,*13(2):86–95.

Wagner D., Christiansen H., Wolff H., Vorwerk H. 2009. Radiotherapy of malignant gliomas: comparison of volumetric single arc technique (RapidArc), dynamic intensity modulated technique and 3D conformal technique. *Radiother Oncol.,* 93:593–6.

Wang Jian Z, Allen Li, D'Souza Warren D, Stewart Robert D. 2003. Impact of prolonged fraction delivery times on tumor control: a note of caution for intensity modulated radiation therapy (IMRT). *Int J Radiat OncolBiol Phys.,* 57:543–52.

White P. Chan KC, Cheng KW et al., 2013. Volumetric intensity modulated arc therapy vs conventional intensity-modulated radiation therapy in nasopharyngeal carcinoma: A dosimetric study. *J Radiat Res.,* 54:532-545.

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