Reseach Article

RapidArc vs IMRT: Our Experience in Head and Neck Cancers-A Dosimetric Study

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Abstract

Introduction: To compare double arc (DA), Sliding window (SW) & Step and shoot (SS) IMRT in Head & neck cancer (HNC) by different dosimetric parameters.

Materials and methods: 25 cases of HNC were planned for DA, SW & SS IMRT by Treatment Planning System-Eclipse (version 10.0) between September 2012 to February 2013. Primary end points were target coverage and doses to organs at risk (OARs). The secondary end points were the treatment time (TT) and the monitor units (MUs). Statistical analysis was done using K independent sample test and paired t test.

Results: The coverage for target volumes were similar by all the three techniques (p>0.05). There were also no difference in Homogenity Index (HI) and Conformity Index (CI) (p>0.05). Dmean to OARs were maximum with DA followed by SW and SS IMRT. Ipsilateral parotids, contralateral parotids and dysphagia aspiration risk structures (DARS) received higher mean dose by DA than by SW and SS IMRT (p<0.05). The Dmax for Brain stem and 1% volume of spinal cord was least by SS IMRT (p<0.05). The difference in Dmean between SW and SS IMRT for oral cavity was 0.5 ± 0.10Gy (p<0.05). However, DA had the advantage of requiring minimum number of MUs (p<0.05) and TT (p<0.05) in comparison to SW and SS IMRT.

Conclusion: DA gave the advantage of minimum number of monitor units and least total treatment time over SS and SW IMRT. However, it was indifferent for target coverage, homogeneity and OAR sparing.

ABBREVIATIONS

DA: Double Arc; SS: Step and Shoot; IMRT: Intensity Modulated Radiotherapy; SW: Sliding Window; HNC: Head & Neck Cancer; TT: Treatment Time; MU: Monitor Units; HI: Homogenity Index; CI: Conformity Index; OAR: Organs at Risk

INTRODUCTION

Intensity modulated radiotherapy (IMRT) in head and neck cancers (HNC) has been in use for around two decades. It has clearly been seen that IMRT results not only in a better dose distribution profile to organs at risk (OAR) when compared to 3 dimensional conformal planning [1], but also in an improved 2 year overall survival [2], progression free survival [2], locoregional control [3], and quality of life [1]. IMRT has the unique capability of producing inhomogeneous dose distributions, allowing simultaneous delivery of different doses per fraction to different areas within the treatment field. It has the potential radiobiological advantage of reducing the impact of accelerated repopulation in tumor clonogens by using simultaneous integrated boost (SIB) technique [4]. Increasing use

of IMRT has also witnessed a growing concern regarding second malignancies as a result of an increase in the treatment time [5], worsening the accuracy of treatment due to increased intra fractional patient motion [6], and reduction of patient throughput with economic consequences. Besides, it also leads to patient discomfort on the treatment couch and affects reproducibility of treatment position. Having seen the superiority of IMRT across all the sites, various authors have now started looking at different techniques of IMRT with respect to the dose distribution to the target volumes, OARs, number of monitor units (MUs) required and the treatment time required to deliver the desired dose. It has been seen in various studies that techniques like Volumetric arc modulated therapy (VMAT), first introduced in 2007, results in fast delivery of radiation, provide better sparing of OARs and provide more uniform and conformal dose distributions to the target volumes as a result of various factors such as continuous modulation of multileaf collimators (MLC), field shape, fluence rate, gantry rotation speed and collimator angle [7]. This may also enable more frequent online imaging. This is important as Zeiden, et al., demonstrated an incidence of 11% set up errors of more than 5 mm in 3DCRT for HNC patients [8].

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The different techniques of IMRT that have been practiced and described in literature are "step and shoot"(SS), sliding window (SW), volumetric modulated arc (single arc (SA) and multiple arcs (MA) as VMAT by Elekta, RapidArc (RA) in the Eclipse treatment planning software (Varian Medical Systems, Palo Alto, CA) and SmartArc by Phillips). The term IMAT (Intensity modulated arc therapy) has been used to describe delivery of IMRT using multiple rotational arcs whereas the term AMRT (arc modulated radiotherapy) has been used to describe the delivery of IMRT by single arc.

There are not many studies comparing treatment planning and dosimetric parameters by different IMRT techniques, especially in head and neck cancers. The results of these limited studies are mixed. Some studies have revealed that SA VMAT does not succeed in achieving a plan quality comparable to IMRT [9-11], while others suggest that a SA is good enough [7,12]. We have therefore performed a comparison of SS IMRT plans with SW IMRT and Double arc (DA VMAT) on same treatment planning system (TPS-Eclipse version 10.0).

MATERIAL AND METHODS

Twenty five cases of head-and-neck cancers were planned for IMRT at our department during the period September 2012 to February 2013. It was a prospective study. This study is prospective. 3 plans were generated one each for the individual technique and dosimetric comparisons were made as explained in the paper. It was only for research purpose in this particular study. However our study did not intent to collect the information about the plan which was selected for individual patient.

Staging was done using TNM classification (UICC 7th edition).

Patients were immobilized from head to shoulders using thermoplastic masks. Computed tomography (CT) images (5 mm slice thickness) were acquired from the top of the vertex to the level of the carina on a CT simulator (Somatom sensation open, Siemens Medical system, Germany). Contouring was done on Somavision by Varian Medical System. The gross tumor volume (GTV) covered the visible primary tumor and neck nodes > 1 cm in diameter in short axis or nodes with necrotic centers as shown by CT/MRI/PET fusion images. The clinical target volume (CTV) encompassed the GTV with at least a 1.5 cm margin, microscopic spread of disease, and prophylactic neck area. The planning target volume (PTV) included the CTV with 3-5 mm extensions in all dimensions to account for patient setup error and motion uncertainties. The prescribed dose was 70 Gy/35 fractions to the GTV, 63 Gy /35 fractions to the CTV and PTV each & 56 Gy/35 fractions to the elective clinically negative neck region with a daily fraction size of 2 Gy, 1.8 Gy and 1.6 Gy respectively in five fractions per week. Radiotherapy was delivered using a SIB technique on for the Linac Model - VARIAN CLINAC ix of Varian Medical System, Palo Alto.

For each patient, following OARs were identified: spinal cord (s.c), brainstem, and parotid glands (ipsilateral and contralateral). Oral cavity, larynx and dysphagia aspiration risk structures (DARS) were also contoured in selected patients.

Primary end points were set to be the treatment planning goals such as D_{98}% (minimum dose to 98%), D_2% (maximum dose to 2%), maximum point dose (Dmax), mean dose (Dmean), homogeneity index (HI) and conformity index (CI) to the target volume and Dmean, Dmax and Dminimum to organs at risk(OARs). The secondary end points were the trade-offs like the treatment time (TT) and the monitor units (MUs).

Planning steps

In order to ascertain a fair comparison, the plans were generated on the same TPS (Eclipse version 10.0 by Varian Medical Systems) keeping all the parameters similar. MLC leaf width was 0.5cmx80 at isocenter with opening of 40x40 cm. The basic planning parameters included the beam isocentre, prescribed dose and optimization constraints.

A fixed collimator angle of 30° was used for first arc and 330° for the second arc. The first arc moved from 181° to 179° in clockwise manner and the second arc moved from 179° to 181° in an anti clockwise manner. SS IMRT and SW IMRT plans were done using 7 gantry angles (60°, 100°, 150°, 180°, 210°, 260° and 300°) at 0° collimator angle for each gantry angle (Figure 1).

Eclipse treatment planning system uses direct aperture optimization (DAO) algorithm for IMRT optimization and progressive resolution optimization (PRO) algorithm for VMAT optimization. Calculation grid used in calculation was 2.5 mm.

The doses were calculated using analytical anisotropic algorithm (AAA) for plannings of IMRT as well as VMAT.

Treatment plan evaluation

Plan evaluation was done on Somavision platform of ARIA network by Varian. All plans were evaluated by Radiation Oncologist by analyzing 3D dose distribution for each section (Figure 2) and the dose volume histogram (DVH). A number of dosimetric parameters for PTVs and OARs were analysed.

There are various formulae mentioned in literature for HI. Here it was calculated by using most commonly used formula

HI = $[(D_2 - D_{98}) \div D_{Mean}]$

CI was calculated using formula (RTOG)

CI= Volume of the reference isodose ÷ Volume of target

Statistical methods

The Statistical Package for Social Sciences (SPSS) version 16.0 was used. Paired t test were applied to compare the different dosimetric parameters.

RESULTS AND DISCUSSION

Mean age of the patients was 57.32 ± 11.66 yrs (44-92 yrs).

Table 1: Site wise distribution of patients.

Site	N
Oral cavity	3
Oropharynx	14
Hypopharynx	5
Nasopharynx	3
N= number of patients	

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Table 2: Mean ± SD dosimetric results for GTV and PTV.

	DA VMAT	SW IMRT	SS IMRT
GTV D98% 50% D2%	(70.9±0.98)Gy (72.6±0.81)Gy (73.7±0.80)Gy	(70.7±1.01)Gy (72.3±0.92)Gy (73.7±1.02)Gy	(70.5±0.75)Gy (72.2±1.05)Gy (73.6±0.64)Gy
PTV D98% D50% D2%	(59.9±1.22)Gy (66.8±2.06)Gy (73.1±1.56)Gy	(60.0±1.38)Gy (66.5±1.59)Gy (73.2±0.79)Gy	(59.7±1.15)Gy (66.2±1.66)Gy (73.1±0.60)Gy
CI	0.96±0.01	0.94±0.01	0.94±0.02
HI	0.197±0.03	0.198±0.01	0.196±0.02

Abbreviations: GTV: Gross Tumour Volume; PTV: Planning Target Volume; CI: Conformity Index; HI: Heterogeneity Index; DA VMAT: Double Arc Volumetric Modulated Arc Therapy; SW IMRT: Sliding Window Intensity Modulated Radiation Therapy; SS IMRT: Step and Shoot Intensity Modulated Radiation Therapy.
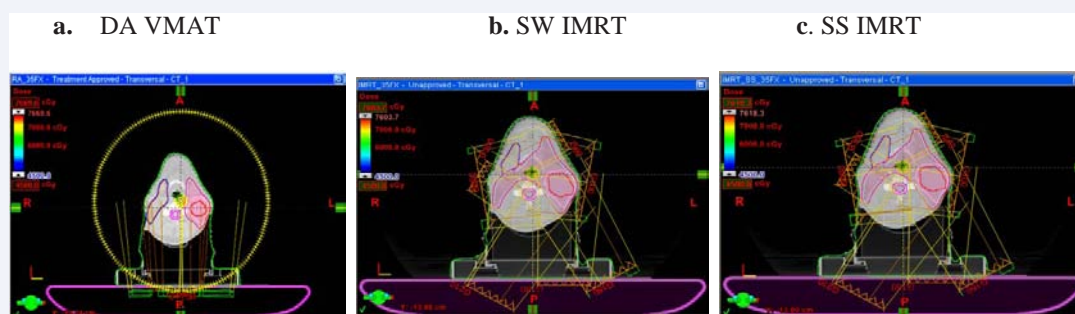

Figure 1 Axial computed tomography slice showing the field arrangement for: (a) Double Arc Volumetric modulated arc therapy(DA VMAT), (b) Sliding window intensity modulated radiotherapy(SW IMRT), (c) Step and shoot intensity modulated radiotherapy.

Figure 2 Dose distributions on axial, coronal and sagittal views by (a) Double Arc Volumetric modulated arc therapy (DA VMAT), (b) Sliding window intensity modulated radiotherapy (SW IMRT), (c) Step and shoot intensity modulated radiotherapy.
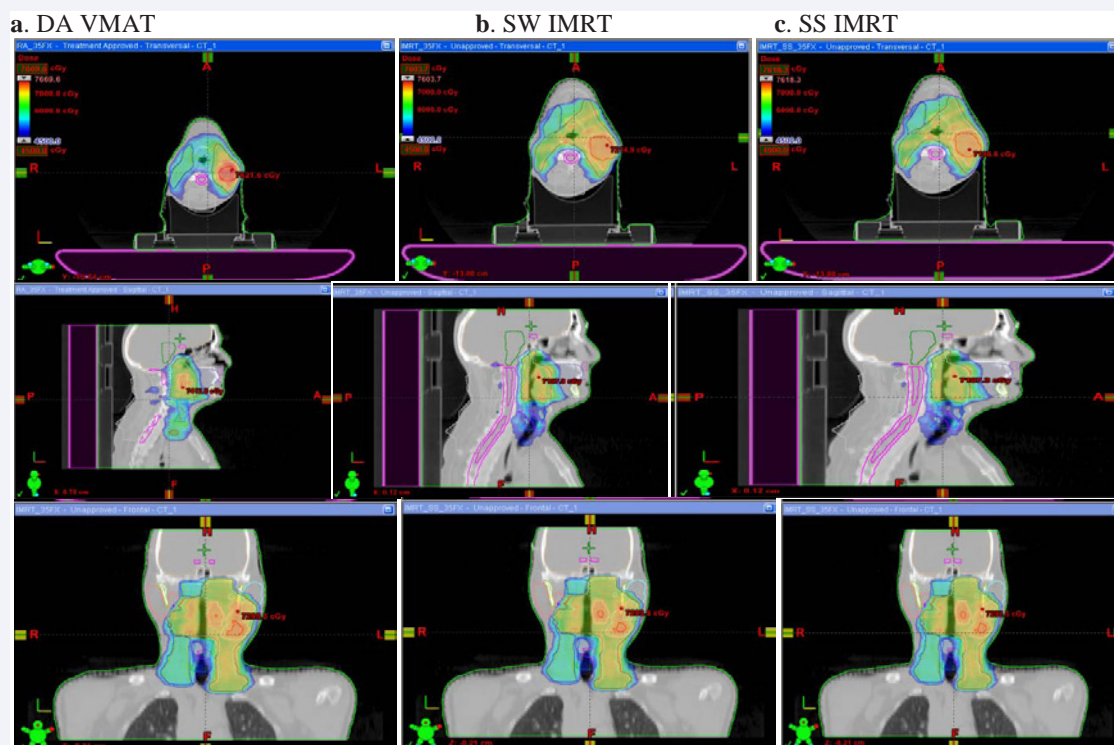
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8 (12%) patients were in stage III, 2 were in stage IVB (8%) and 20(80%) were in stage IVA. Site wise distribution has been shown in Table 1. The primary GTV volume ranged from 3.10- 95.00 cc (mean- 34.73 ± 27.53 cc) and the Primary PTV volume ranged from 244.4- 749.70 cc (mean- 453.00 ± 139.6 cc).

Coverage

The coverage for 98%, 2% and 50% GTVs and PTVs were similar for plans by DA VMAT, SW IMRT and SS IMRT (Table 2 and Figure 3).

There was no significant difference in the H.I. and C.I. amongst all three plans (Table 2).

The mean dose to ipsilateral parotids (Table 3) was significantly higher (41.6 Gy) by DA VMAT as compared to SW IMRT (39.6 Gy; p=.01) and SS IMRT (39.5 Gy; p=.003).

The mean dose to contralateral parotids (Table 3) was significantly higher (30.5 Gy) by DA VMAT as compared to SW IMRT (28 Gy; p=.01) and SS IMRT (28.2 Gy; p=.021).

The dose to 1% S.C. was significantly higher (p=.000) with DA VMAT as compared to SW and SS IMRT and was significantly lower with SS IMRT as compared to SW IMRT (p=.038) (Table 3 and Figure 3).

The maximum point dose to brainstem was significantly lower with SS IMRT as compared to DA VMAT (p=.001) and SW IMRT (p=.004) (Table 3).

The mean doses to DARS (Table 3 and Figure 3) was significantly high by DA VMAT as compared to SW IMRT (p=.038) and SS IMRT (p=.004). There was however, no significant difference between SW and SS IMRT.

The mean dose to oral cavity was least with SS IMRT as compared to SW IMRT (p=.002) and DA VMAT (p=.607). However, the mean dose by DA VMAT and SW IMRT were similar (p=.985).

The only areas where DA VMAT had a clear edge over other two techniques were the number of MUs and total treatment time. The mean numbers of MUs delivered by DA VMAT were 441.28 as compared to 1612.12 by SW IMRT and 1444.52 by SS IMRT. The mean treatment time by DA VMAT was 1.1 minute as compared to 5.37 minutes by SW IMRT and 4.8 minutes by SS IMRT (Table 3).

Results: Site wise

Oral cavity: Coverage, homogeneity and conformity were similar for the target volumes. There was no difference in brain stem and spinal cord sparing; also none of the technique was better for DARS, ipsilateral and contra lateral parotids.

Oropharynx: There was no difference in target coverage, homogeneity and conformity. No better sparing of spinal cord was observed. For Brain stem (Dmax) DA VMAT generated maximum mean dose followed by SW and SS IMRT respectively (44.48 ± 2.24 Gy, 42.28 ± 2.71 Gy and 41.85 ± 2.62). The difference in the dose was significant between DA VMAT and SS IMRT (p=0.003). Significant difference was also observed for DARS, oral cavity, contralateral parotid and ipsilateral parotid. For all these OARs the mean dose was maximum with DA VMAT followed by SW

AND SS IMRT. The p value for DARS were 0.025(SW and SS IMRT), 0.049(DA VMAT and SS IMRT). For oral cavity also the difference in was significant between SW and SS IMRT (p=0.005). For contralateral and ipsilateral parotid the higher dose shown by DA VMAT was found to be significant with a p value of 0.022 and 0.030 over SW IMRT and a p value of 0.058 and 0.018 over SS IMRT.

Hypopharynx: There were no difference in target coverage, conformity and heterogeneity. For spinal cord SS IMRT and SW IMRT were found to be different with a p value of 0.002. DA VMAT showed significant difference over SW and SS IMRT (p=0.018 and 0.013) for Brain stem. SW IMRT spared maximum contralateral (25.28 Gy) and ipsilateral parotid (28.84 Gy) over SS IMRT and DA VMAT(26.07 Gy, 27.31 Gy and 29.22 Gy, 31.06 Gy respectively) but it was non significant. Oral cavity had similar dose distribution.

Nasopharynx: GTV coverage, $PTV_{2\%}$ CI, HI, sparing of brain stem and spinal cord were non- different. Mean value for $PTV_{98\%}$ were 58.27 Gy, 59.82 Gy and 59.84 Gy by DA VMAT SW IMRT and SS IMRT. SW IMRT showed significant difference over DA VMAT (p=.049) and SS IMRT (p=.029). Likewise it was for $PTV_{95\%}$ difference with p values of 0.045 and 0.025. However SW IMRT differed significantly with DA VMAT only for $PTV_{50\%}$. Contralateral and ipsilateral parotid had significant different dosimetry by SW IMRT over SS IMRT (p=.038) and (p=.025) respectively. But their mean doses were maxium by DA VMAT followed by SW IMRT then SS IMRT. For lens (both right and left) the mean doses were higher by SW IMRT (8.54 Gy &10.50 Gy) than DA VMAT (5.22 Gy & 8.41 Gy) and SS IMRT (8.33 Gy & 10.31 Gy).

Discussion

Yu, [13], proposed the term IMAT in 1995. However, it was only after the publication of work by Otto, [7], in 2007 that comparative studies of IMAT with fixed beam IMRT have increasingly been done.

A review of available literature, mostly dosimetric comparisons, makes one feel that there are diverse results regarding coverage of PTV and OARs by different techniques like SS IMRT, SA VMAT, DA VMAT, Triple arc (TA VMAT) and helical tomotherapy (HT). The difference in number of monitor units delivered and overall treatment time is important with the growing concern of rising incidence of second malignancies [14].

Following initial studies of VMAT using single arc [7], Guckenberger, et al. [9], and Doornaert, et al. [10], published studies on use of more than one arc. In agreement with studies of comparison between SA VMAT and DA VMAT in HNC patients [11,15], and realizing the benefit of DA over SA in terms of coverage and better homogeneity, we chose to plan our cases with DA.

Yu, [13], used 2 to 5 arcs and Cao, et al. [16], have described IMAT planning with 4 to 5 arcs for target volumes of intermediate complexity and even 9 arcs for treatment of HNC cases with 3 dose levels.

Verbakel, et al. [11], have reported on 12 patients of HNC cases and compared SA VMAT and DA VMAT with 7 fields SS IMRT. They found similar coverage of PTV between SS IMRT and VMAT

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and found no significant difference in doses to OARs. Parotids received a slightly lower mean dose (average of 2 Gy) with DA VMAT as compared to SA VMAT and SS IMRT. Homogeneity was better using DA VMAT then with SA VMAT. Gestel, et al. [20], observed better homogeneity with RA [10], than SS IMRT [11], while SW and RA were similar [10]. In our study, the coverage for 98%, 2% and 50% GTVs and PTVs were similar for plans by DA VMAT, SW IMRT and SS IMRT .There was no significant difference in the H.I. and C.I. amongst all three plans (Table 2).

Vanetti, et al. [15], in their study of 29 patients reported similar PTV coverage and conformity between SA VMAT and DA VMAT and better homogeneity in DA VMAT plans. The mean doses to OARs were significantly lower in SA VMAT plans. D 2% for spinal cord was 39 Gy and 42.8 Gy in DA VMAT and SS IMRT respectively. Similarly, the brainstem D 2% was 23.8 Gy and 38.2 Gy for DA VMAT and SS IMRT respectively. In our study, the dose to 1% S.C. was significantly higher (p=.000) with DA VMAT as compared to SW and SS IMRT and was significantly lower with SS IMRT as compared to SW IMRT (p=.038).The maximum point dose to brainstem was significantly lower with SS IMRT as compared to DA VMAT (p=.001) and SW IMRT (p=.004) The mean doses to DARS (Table 3) was significantly high by DA VMAT as compared to SW IMRT (p=.038) and SS IMRT (p=.004). There was however, no significant difference between SW and SS IMRT. The mean dose to oral cavity was least with SS IMRT as compared to SW IMRT (p=.002) and DA VMAT (p=.607). However, the mean dose by DA VMAT and SW IMRT were similar (p=.985).

In a study by Vanetti, et al., the contralateral parotids received mean dose of 28.2 Gy with DA VMAT and 32.6 Gy with SS IMRT while the ipsilateral parotid received a mean dose of 34.4 Gy with DA VMAT and 40.1 Gy with SS IMRT plans. They reported a reduction by 7% in the integral dose to the body by use of VMAT plan. In our study, The mean dose to ipsilateral parotids in our study as shown in Table 3, was significantly higher (41.6 Gy) by DA VMAT as compared to SW IMRT (39.6 Gy; p=.01) and as compared to SS IMRT (39.5 Gy; p=.003).The mean dose to contralateral parotids (Table 3) was significantly higher (30.5 Gy) by DA VMAT as compared to SW IMRT (28 Gy) (p=.01) and SS IMRT (28.2 Gy; p=.021).

Johnston, et al. [17], have also reported better sparing of contralateral parotid and comparable PTV coverage between VMAT and SS IMRT plans. Holt, et al. [22], observed in oropharyngeal cancers (n=5) better sparing of OARs by VMAT.

Bertelsen, et al. [12], conducted a study of 25 HNC cases comparing SA VMAT with SS IMRT. They also found similar PTV coverage with slightly better conformity in the elective nodal volume with VMAT. They however used only 5 to 7 fields in SS IMRT as compared to 7 to 9 fields used by most other studies.

Another study by Guckenberger, et al. [9], compared 9 field SS IMRT with SA, DA and TA VMAT in 10 patients of HNC (primary pharyngeal and post operative) and 5 cases of paranasal sinuses (PNS). All VMAT plans were inferior to SS IMRT for dose coverage especially in area between the orbits. Both SA VMAT and DA VMAT were inferior to SS IMRT in primary pharyngeal patients. In post operative cases also, the PTV coverage was inferior in SA VMAT as compared to SS IMRT. The DA VMAT plans were equivalent to IMRT and TA VMAT were superior in terms of PTV

coverage and homogeneity. In our study in ca nasopharyngeal cases mean dose to either lens was higher with SW IMRT than SS IMRT and DA VMAT.

Sankaralingam, et al. [18], have also concluded that VMAT does not offer significant improvement in dosimetric parameters in the treatment of cases on sino nasal cancers.

Putting all the studies together, a similar coverage of the target volumes has been reported by Vanetti, et al., Johnston, et al., Bertelson, et al., Cao, et al., and Moret, et al. [19], between various plans. Similar coverage has been seen in our study also.

Homogeneity

An inhomogeneous dose in PTV can lead to a substantial decrease in the tumor control probability.

Some authors have reported a better homogeneity by DA VMAT than SA VMAT and SS IMRT [11,19], while others reported that SS IMRT had better homogeneity as compared to SA VMAT [15,17]. Homogeneity was equal between VMAT and SS IMRT [12,20]. We have seen a similar homogeneity amongst the three plans. Verbakel, et al. [11], have given an explanation of how the sum of 2 arcs reduces hot spots in the PTV when the first rapid arc plan is used as a base dose plan, after which the second arc compensates for areas of suboptimal dose. Besides, the limited leaf speed and the limited control points for a single arc makes it possible for DA to permit better homogeneity.

Conformity

In a study by Fung-Kee-Fung, et al., IMRT plans were more conformal with a lower conformity index (CI =1.61) than VMAT (CI=2.00). Bertelson, et al. [12], have reported a better conformity with VMAT plans, while Johnston, et al. [17], have shown better conformity with SS IMRT. An equivalent CI between the two has been reported by Vanetti, et al., and so has been the case in our study. Theoretically, VMAT utilizes full gantry range and should provide better conformity [7].

MUs and treatment time

One of the major advantages of VMAT over SS IMRT especially SW IMRT is the reduction in MU (upto 46%) and resultant decrease in delivery time especially when the number of IMRT fields used was 7 to 9 as compared to 5 field plans [11,12,15,17,20]. We have seen that there was a significant difference of more than 3 times in the number of MUs and treatment delivery time in the SS and SW IMRT as compared to DA VMAT (Table 3). Dose received outside the target volume increases in IMRT with higher MUs as compared to VMAT. But VMAT increases the integral dose to the patient.

CONCLUSION

A blanket statement that SA VMAT gives a better dose distribution profile than SS IMRT cannot and should not be made, for a lot depends on the site of the tumor. Whereas it has generally been seen that VMAT improves target coverage and dose homogeneity, it can also increase the spread of low dose to certain normal tissues like the lenses and area between orbits in case of tumors of the paranasal sinuses [9]. It will depend on the complexity of the target volume on a case to case basis.

Table 3: Average dose ± SD dosimetric results for organs at risk.

	DA VMAT	SW IMRT	SS IMRT	p value
I. Parotid(Gy)	(41.6±13.95)	(39.6±13.55)	(39.6±13.44)	X(95%CI, 0.53-3.50), Y(95%CI,0.75-3.3)
C. parotid(Gy)	(30.5±7.47)	(28.0±7.68)	(28.2±7.23)	X(95%CI, 0.65- 4.31), Y(95%CI, 0.37- 4.28)
Dose to 1% Vol. Spinal cord(Gy)	(38.6±2.55)	(34.3±2.77)	(34.2±2.84)	X(95%CI, 2.51- 5.29), Y(95%CI,2.80- 5.85), Z(95%CI,0.28- 0.90)
Brain Stem Dmax(Gy)	(46.0±3.78)	(42.4±4.09)	(41.9±3.90)	X(95% CI,1.74-5.57), Y(95% CI, 5.9- 9.94), Z(95%CI, 0.15- 0.69)
Oral cavity Dmean(Gy)	(44.4±6.75)	(44.4±4.77)	(43.9±4.81)	Z(95% CI, 0.27- 0.86)
DARS Dmean (Gy)	(58.1±4.76)	(55.2±4.45)	(54.1±4.56)	X(95%CI, 0.26- 5.63), Y(95%CI, 2.18- 5.83)
MUs	441.2±43.70	1612.1±262.29	1444.5±239.94	X(95%CI, -1272- -1069), Y(95%CI, -1094.22- -912.25), Z(95%CI, 129.35-205.34)
Treatment Time(minutes)	(1.10±0.11)	(5.37±0.87)	(4.80±0.78)	X(95%CI, -4.60- -3.92), Y(95%CI, -4.0- -3.39), Z(95%CI, 0.44-0.69)

Abbreviations: I.: Ipsilateral; C.: Contralateral; Vol.: Volume; DARS: Dysphagia Aspiration Risk Structures; MUs: Monitor Units; DA VMAT: Double Arc Volumetric Modulated Arc Therapy; SW IMRT: Sliding Window Intensity Modulated Radiation Therapy; SS IMRT: Step and Shoot Intensity Modulated Radiation Therapy; p = Statistical significance (p < 0.05) is reported between couples from paired t-test analysis; X: DA VMAT vs SW IMRT; Y: DA VMAT vs SS IMRT; Z: SW IMRT vs SS IMRT.

Hence we maintain that rival plans of SA VMAT, DA VMAT and SS IMRT should be generated for each individual case. A thorough comparison of target coverage, dose to normal tissues, delivery times and MUs keeping in mind the importance of organ motion and second malignancies in young age individuals should be made. VMAT may contribute little in improving dose distributions, but its impact on faster delivery of treatment and less number of MUs is important.

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