Panacea Journal of Medical Sciences 2022;12(3):582–589

Content available at: https://www.ipinnovative.com/open-access-journals

Panacea Journal of Medical Sciences

Journal homepage: http://www.pjms.in/

Original Research Article

Dosimetric analysis of 3 dimensional conformal radiotherapy with volumetric modulated arc therapy in patients with carcinoma oesophagus – Prospective study

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ARTICLE INFO

Article history:
Received 20-05-2022
Accepted 25-09-2022
Available online 28-11-2022

Keywords:
Radiation Therapy Oncology Group (RTOG)
Volumetric Modulated Arc Therapy
Planning Target Volume
3dimensional conformal radiation therapy

ABSTRACT

Aims: To study the dosimetry and treatment plan of Volumetric Modulated Arc Therapy and 3 Dimensional Conformal Radiotherapy in patients with carcinoma oesophagus.
Materials and Methods: A prospective study was taken up in Department of Radiotherapy, from October 2017 to June 2019. A total 20 patients who achieved eligibility criteria was taken into study and both 3D CRT (3D Conformal Radiation Therapy)and VMAT(Volumetric Modulated Arc Therapy) plans was done in all patients. Dosimetric comparison is done between these two techniques.
Results: Dose to spinal cord is significantly reduced with VMAT technique when compared to 3D CRT. VMAT plans in this study showed significantly reduced doses to heart, when compared to 3D CRT plans. VMAT plans decrease volume of lung receiving high dose(v20,dmean,v30,v40) compared to 3D CRT but at a cost of delivering low dose to more volume of lung (v5, v10, v15) resulting in serious complications like radiation pneumonitis.
Conclusion: VMAT plans are advisable in carcinoma oesophagus patients to achieve reduced doses to OARs(Organs at Risk) like Spinal Cord, Heart & Lung and better target coverage particularly in cervical esophagus where higher doses are planned.

1. Introduction

Oesophageal cancer is the 8^{th} most common cancer worldwide.[1] In 2012, estimated 455,784 new oesophageal cancer cases was diagnosed and approximately 400,156 deaths occurred worldwide. In India it is the 4^{th} common among cancer and the 3^{rd} common cancer related mortality.[2] The projected incidence of oesophageal cancer in India by 2020 is estimated to be 42,513.[3] Radiotherapy is a major treatment method for unresectable oesophageal carcinoma as more than 60% of the patients are diagnosed at an advanced stage which cannot be resected.

Treatment planning and delivery for oesophageal cancer has progressed rapidly over the past 5 years. 3D Conformal Radiation Therapy (3D-CRT) was the planning method of choice for many years. Innovative technologies in radiation delivery such as Intensity Modulated Radiotherapy (IMRT) offer the potential for improved tumour coverage, while reducing the doses delivered to the surrounding normal tissues. Clinical studies has yielded good dosimetry and patient outcome by IMRT.

To reduce the radiation dose to critical normal structure integration of different planning modality is required. VMAT, through the dynamic modulation of angular dose rate and multi-leaf collimator motion, can achieve a highly conformal dose distribution while decreasing treatment time. Due to its shorter treatment times, the likelihood of

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https://doi.org/10.18231/j.pjms.2022.110

patient movement during treatment, which can potentially lead to Planning Target Volume (PTV) miss is reduced. The no of studies comparing 2 techniques are limited on Indian population. Hence there is strong need to conduct studies comparing dosimetry properties of 3D CRT and VMAT on Indian population. This study finding may enhance the existing evidence and in turn guide the therapeutic decision making. In this background, the current study is being undertaken with the aim to compare 3D CRT and VMAT in regard to planning dosimetry in cancer of oesophagus.[4]

2. Materials and Methods

The study was a prospective observational study conducted at department of Radiotherapy, at MNJ Institute of Oncology and Regional Cancer Center, Osmania medical college, Hyderabad, Telangana from October 2017 to June 2019. Patients attending the study setting with carcinoma oesophagus malignancies treated with 3D CRT or VMAT was considered as study population. Minimum of 20 histologically proven newly diagnosed cases of carcinoma oesophagus according to the inclusion and exclusion criteria for radical radiotherapy along with concurrent chemotherapy will be enrolled for the study. Treatment planning will be done for all the patients in study group in both 3D CRT and VMAT techniques and compared

All the eligible subjects willing to participate in the study was sampled consecutively into the study, hence no sampling was done. The dosimetric parameters like Homogeneity Index, Conformity Index, Target Homogeneity (TH), D max, D mean, D98%, D2%, D95%, D5%, Total Monitor Units, and D max, D mean of OARs like spinal cord, Heart, V5,V10, V15, V20, V30 and D mean of combined Lung, V5, V10, V15, V20, V30, V40 of combined Lung was reported for both 3D CRT and VMAT treatment plan.

2.1. Inclusion criteria

Age: 15 – 70 years with histologically-proven Oesophageal Squamous Cell or Adenocarcinoma, ECOG Score Performance: 0 – 2,, Stage Ib to IVa and Curative Treatment Intent

2.2. Exclusion criteria

Distant Metastasis, HIV / HB s AG positive patients, Reirradiation and Multiple Synchronous Malignancies

2.3. Pre – Treatment evaluation

1. Baseline Complete Hemogram (Haemoglobin, Total Count, Differential Count, Platelet Count) and Biochemistry (RBS, LFT, RFT, Serum Electrolytes).
2. HIV/ HBSAG.
3. CECT Neck, Chest and Abdomen.
4. Upper GI Endoscopy.
5. Endoscopic Guided Biopsy.

Pre-treatment QA using Fluence measurements either in Electronic Portal Imaging Device (EPID) or with IMatriXX was routinely employed for all plans in this study. All measured fluences was compared with treatment planning system – evaluated fluences using EPID software in ECLIPSE planning system Version 13.6. Gamma evaluation parameters of 3mm translational distance and 3% dose difference was employed for fluence analysis.

2.4. 3DCRT planning

Three-dimensional conformal plans was incorporated into 2 phases of treatment, with each phase planned separately for the same target volume. Phase I consisted of a parallel-opposed, antero-posterior (AP), and postero- anterior 6 MV photon fields up to a dose of 39.6 Gy, followed by phase II, with three 6 MV photon fields up to a dose of 50.4 Gy. The phase II beam geometry for all patients included an AP field and 2 posterior oblique fields at gantry angles (approximately 100 – 120 and 240 – 260) oriented in such a way to avoid the spinal cord. The 2 posterior oblique beams was wedged to achieve optimum PTV dose distribution.

A margin of 6mmwas allowed between the PTV and the field edge to allow for the beam penumbra. Relative contributions of the phases to the total dose was determined such that the maximum dose to the spinal cord does not exceed 50 Gy and the mean dose to the Lung is 20 Gy. The MU required to give a fixed isocentric dose was then calculated for these separate plans. The MU for both phases was then added together in appropriate proportions, according to the relative isocentric dose delivered by each phase of the treatment.8 The 2 phases of the plan was then combined into a composite plan for dose-volume histogram (DVH).

2.5. VMAT planning

1. Double Arc plans consisted of 2co-planar arcs with the first arc in the clockwise (1810 to 1790) and the other arc in the counter clockwise (179 to 1810) direction.
2. Collimator was rotated 10-150 depending on the plan to cover the entire tumour volume.
3. Fixed jaw arrangement was employed for all plans in this study 28.
4. Minimum monitor units per beamlet is fixed at more than 3 MU.

Informed consent was taken from the patient after explaining the study protocol in detail to the patient and his/her attendants in their own language. Patient was immobilized in supine position using a thermoplastic chest ray cast with hands above head and was given oral contrast and IV contrast. Patient was aligned properly with the help

of laser alignment beams. 4 CT – Simulation and Image acquisition. Each patient underwent a planning CT with oral and intravenous contrast from vertex to umbilicus with slice thickness of 3mm using a Philips Bigbore 16 – slice CT simulator. Orthogonal room lasers was used to place skin markers to verify that no shift occurred between scans. The CT images was transferred online to the ECLIPSE tm (Varian medical system, Palo Alto, CA, USA) treatment planning system (TPS).

All the tumour volumes, nodal volumes, and organs at risk was contoured as per RTOG contouring guidelines. ICRU reports 83 was used to define tumour volumes.[4] Based on an expert panel developed and published consensus contouring guidelines for oesophageal cancer intended for use with intensity modulated radiation therapy (IMRT) and other conformal techniques The gross tumour volume (GTV) is defined on CT slices as a macroscopic primary tumour and involved lymph nodes. Endoscopic evaluation, endoscopic ultrasonography (EUS), and/or barium swallow are helpful. The endoscopic marking of the upper and lower extension of the visible tumour with metallic clips improves the definition of the GTV.

The clinical target volume (CTV) includes the GTV and areas at risk of a microscopic spread of the disease. The superior border of the clinical target volume (CTV) was an expansion of 4 cm above the gross tumour or 1cm above any grossly involved para oesophageal lymph node, whichever was more superior. The inferior border was defined as either 4 cm below the gross disease, or at least 2 cm along clinically uninvolved gastric mucosa if the tumour was distally located to reduce radiation dose to normal stomach. Radially, a 1 cm margin was recommended to include the para oesophageal lymph nodes, with exception of smaller margins of 0.5 cm in areas that interfaced with uninvolved cardiac and hepatic tissue. For distal tumours, the celiac lymph nodes as well as paraaortic and gastrohepatic lymph nodes between the GEJ and celiac axis are included in the CTV. For tumours above the carina, bilateral supraclavicular lymph nodes should be included in the CTV, as well as anterior mediastinal nodes.

Finally, planning target volume (PTV) is a uniform 0.5 cm expansion from the CTV in all directions Organs at risk (OARs) contoured was spinal cord, Heart and Lungs according to DAHANCA, EORTC,GORTEC consensus guidelines for CT based delineation of OARs in head and neck region and RTOG 1106 (contouring atlas for Lungs).

For PTV – 50.4 Gy in 28 fractions 180 cGy per fraction . The study was approved by institutional human ethics committee of Osmania Medical College. Confidentiality of the study participants was maintained throughout the study period.

The type of radiotherapy was used as a primary explanatory variable (3D CRT and VMAT). Various dosimetry parameters PTV, the organs at risk, Monitor Units, explanatory variables) was considered as the outcome variables.

2.6. Statistical analysis

Descriptive analysis of relevant factors like Age, Gender, tumour site, T stage, N stage, Stage grouping, Chemotherapy, Eastern Co-operative Oncology Group (ECOG) Status etc. was carried out by mean and standard deviation for quantitative variables, frequency, and proportion for categorical variables. Data was also represented using appropriate diagrams like bar diagram and pie diagram. Dosimetric parameters was tested for normality using Kolmogorov – Smirnov Test (K–S Test). Since two different plans was generated in the CT image set of every individual patient, the data is considered matched pair. Hence paired tests was used to compare the two plans. For normally distributed variables, paired t-test is used. All the dosimetric values are reported in mean (±SD) and median (minimum-maximum) values. All statistical analyses was carried out with 5% level of significance, and p- value <0.05 was considered as significant. IBM-SPSS V20 and Microsoft Excel was used for statistical analysis and for generation of graphs.

3. Results

Total of 20 (n = 20 subjects was included in the final analysis.

Table 1: Demographic details in study

Age (in years)	**Frequency**	**Percentage**
31-40	2	10%
41-50	8	40%
51-60	4	20%
61-70	6	30%
Sex		
Male	8	40%
Female	12	60%
Site		
Cervical	1	5%
Upper Thoracic	2	10%
Mid Thoracic	17	85%
Lower Thoracic	0	0%
Stage		
II a	6	30%
II b	1	5%
III a	3	15%
III b	9	45%
IV a	1	5%

Out of 20, 2 (10%) are in between 31-40 yrs, 8 (40%) are in between 41-50 yrs, 4 (20%) are within 51-60 yrs and 6(30%) are within 61-70 yrs. Descriptive analysis of sex in study group (N=20) Out of 20 patients, 8 (40%) are male and 12 (60%) are female. Out of 20, 1 (5%) has

involved cervical oesophagus, 2 (10%) has involved upper thoracic, 17 (85%) has involved mid thoracic oesophagus. Descriptive Analysis of tumour TNM Stage in study group (N=20).Table 1

Table 2: Descriptive analysis of histology in study group (N=20)

Histology	Frequency	Percentage
WDSCC	7	35%
MDSCC	12	60%
PDSCC	1	5%
CCT		
YES	15	75%
NO	5	25%
ECOG		
1	17	85%
2	3	15%

Out of 20 patients, 7 (35%) has well differentiated squamous cell carcinoma (WDSCC), 12 (60%) has moderately differentiated squamous cell carcinoma (MDSCC) and 1 (5%) has poorly differentiated squamous cell carcinoma (PDSCC). Out of 20 patients, 15(75%) received concurrent chemotherapy and 5(25%) did not receive concurrent chemotherapy. Out of 20 patients, 17 (85%) has ECOG of 1 and 3 (15%) has ECOG of 2.Table 2

Mean PTV volume was 337.9 (±114.8), the mean of Max dose % of PTV in 3D CRT and VMAT plans the differences between means in study groups was statistically significant.Table 3

The mean dose % , mean of D2%, D 5%, D95%, D98%, TH %, CI%, HI % and MU was 53.12(+-0.75) and 53.04(+-0.98) for 3D CRT and VMAT plans respectively.

The Mean of Spinal Cord D max and T V40% he difference between means in study groups was statistically significant.Table 4

Mean dose % of Heart, mean of V15 % mean of V20% , mean of V30%, mean dose % for Heart was 46.1 (±3.54) and 31.8 (±2.08) for 3 DCRT and VMAT plans respectively. The mean of V5% for Heart, mean of V10 % for Heart was 73.4 (±34.3) and 77.9 (±33) for 3D CRT and VMAT plans respectively. The differences was not significant (p=0.214).

The mean of V5%, V10%, V15%, V30%, V40% of Lung was 66.9 (±19.1) and 78.8 (±21.4) for 3D CRT and VMAT plans respectively. The difference between means was statistically significant (p = 0.004). The median of V5% of Lung was 66.8 and 84.1 for 3D CRT and VMAT plans respectively.

The mean of V20% of Lung was 20.7 (±11.9) and 23.6 (±11.7) for 3D CRT and VMAT plans respectively. The difference between means was statistically not significant (p = 0.216). The median of V20% of Lung was 19.02 and 22.8 for 3D CRT and VMAT plans respectively.

4. Discussion

The study shows 40% of patients are within 40-50 years of age followed by 61 – 70 years of age (30%), followed by 51-60 years (20%) and 10% are within 31-40 years of age. Population based data shows that oesophageal cancer incidence peaks at the age of 60 years in most parts of the world.[4] Study population consists of 60% of females and 40% of males. Tumour Site: 85% are middle thoracic oesophagus (85%), 10% are upper thoracic and 5% are cervical oesophagus. Stage of IIIb was seen in 9 (45%) of the study subjects, which was the highest followed by Stage of IIA (30%) subjects. Stage of IIb and stage IVA was seen in 1 (5%) subjects each, which was the lowest to be reported. Major histopathological variant was Moderately Differentiated Squamous Cell Carcinoma in 12(60%) subjects followed by Well Differentiated Squamous Cell Carcinoma and Poorly Differentiated Carcinoma in 7 (35%) and 1 (5%) subjects respectively.

In this study Dmax % of PTV of VMAT is better than that of 3D CRT. The difference between means was not statistically significant. PTV coverage was little better for VMAT. In study conducted by Wu & Xie et al,[5] D max of PTV was better for 3 DCRT than VMAT (63.9 ± 1.75 vs 61.8 ± 1.09, p<0.02). It is in contrast with our study. In study conducted by Jimenez et al,[6] target coverage was better for VMAT than 3D CRT (p=0.05). It is comparable to our study.

In study conducted by Fawaz et al,[7] D Max and D mean was better for VMAT than 3D CRT (p=0.04, p=o.02). it is comparable to our study. The differences in means of D2% was not significant (p=0765). The mean of D5% was 52.7 (±0.44) and 52.7 (±0.97) for 3D CRT and VMAT plans respectively. The differences between the means is statistically not significant (p=0.749). In D95% differences between the means was not statistically significant (p=0.201).

The mean of D98% differences between was not statistically not significant (p=0.269). In study conducted by there was increase in PTV coverage in VMAT but D Max was reduced with respect to 3D CRT. D98% was increased for VMAT, D2% was decreased for VMAT.

The mean of CI% differences was statistically not significant (p=0.07). 3D CRT and VMAT Target. Conformity was comparable with3D CRT and VMAT in our study. The mean of TH differences was statistically not significant (p=0.112). The mean of HI% was 3.81 (±0.98) and 0.11 (±0.02) for 3D CRT and VMAT plans respectively. The differences between the means was statistically significant (p=0.004). VMAT plan allows better target homogeneity than 3D CRT in our study.

In study conducted by Vivekanandan et al,[8] VMAT allows better target conformity (1.01±0.03 vs 1.81±0.06, p=0.006).HI was almost same for VMAT and 3D CRT(4.83±0.6 vs 5.2±2.18, p=NS) but has better target coverage. These results are in contrast to our study. In study

Table 3: Comparison of dosimetric parameters of PTV in 3D CRT and VMAT

	3D CRT				VMAT				p-value
PTV	**Mean (± SD)**	**Median**	**Min**	**Max**	**Mean (± SD)**	**Median**	**Min**	**Max**	
Volume (cc)	337.9 (±114.8)	310.5	187	593.5					
D max	106.12 (±0.88)	106.2	104.4	108.3	107.8 (±1.8)	107.6	104	111.7	0.002
D Mean	101.5 (±0.87)	101.5	99.2	103	102.3 (±1.56)	102.05	99.6	107.7	0.073
D2%	53.12 (±0.75)	53.1	53.2	55.7	53.04 (±0.98)	53.05	50.3	54.6	0.765
D5%	52.7 (±0.44)	52.8	51.5	53.5	52.7(±0.97)	52.8	50	54.3	0.749
D95%	48.9 (±0.85)	49.1	46	49.7	48.4 (±1.01)	48.5	48.3	49.7	0.201
TH	3.81 (±0.98)	3.55	2.3	6.5	4.3 (±0.1)	4.15	2.7	6.1	0.112
D98%	48 (±1.16)	48.4	44.7	49.3	47.5 (±1.21)	47.5	43.4	49.4	0.269
CI	0.95 (±0.06)	0.97	0.83	0.99	0.972 (±0.018)	0.97	0.907	0.99	0.07
HI	3.81 (±0.98)	3.55	2.3	6.5	0.11 (±0.02)	0.11	0.07	0.15	0.004
MU	380.15 (±91.6)	384.5	205	579	406 (±35.7)	401	353	467	0.27

Table 4: Comparison of OARS in 3D CRT and VMAT

	3D CRT				VMAT				p- value
OAR's	**Mean (± SD)**	**Median**	**Min**	**Max**	**Mean (± SD)**	**Median**	**Min**	**Max**	
Spinal Cord - Dmax	46.1 (±3.54)	46.6	35.7	52.9	31.8 (±2.08)	32.3	27.6	35.2	0.001
Heart - Dmean	30.6 (±12.51)	34.3	3.1	44.6	21.25 (±8)	22.9	4.2	40.4	0.002
Heart – V5	73.4 (±34.3)	90.7	0	100	77.9 (±33)	96.3	0.05	100	0.214
Heart – V10	67.4 (±33.6)	79.9	0	99.1	71.22 (±31.9)	84.5	0	99	0.327
Heart – V15	64.6 (±32.7)	76.8	0	97.9	56.27 (±26.1)	64	0	87.4	0.07
Heart – V20	62.2 (±32.6)	76.8	0	97	40.35 (±18.9)	46.4	0	63.7	<0.001
Heart – V30	55.2 (±31)	64.1	0	95.1	18.8 (±11.19)	20.2	0	36.3	<0.001
Lung - Dmean	12.9 (±4.3)	12.8	3.25	23.7	14.5 (±4.41)	15.4	3	21	0.008
Lung – V5	66.9 (±19.1)	66.8	13.15	96.3	78.8 (±21.4)	84.1	14.4	99.9	0.001
Lung – V10	37.6 (±16.3)	35.2	9.2	83.9	67 (±22)	66	10	98	0.002
Lung – V15	24.6 (±13.4)	23.2	6.45	70.7	43.1 (±19.6)	43.75	5.7	71.2	0.002
Lung – V20	20.7 (±11.9)	19.02	5.65	62.1	23.6 (±11.7)	22.8	3.1	41.7	0.216
Lung – V30	14.35 (±5.68)	14.85	1.9	25.2	7.22 (±3.8)	7.25	1	15.1	0.002
Lung – V40	9.9 (±4.11)	10.8	1.1	18.7	2.97 (±1.56)	2.95	0.3	7.1	0.002

conducted by Wu & Xie et al,[5] CI95% was more for VMAT compared to 3D CRT(0.8±0.1 vs 0.5±02, p<0.01).this is in contrast with our study. HI was better for VMAT compared to 3D CRT. This is comparable with our study. In study conducted by Jimenez et al,[6] HI and CI was better for VMAT compared to 3D CRT (p<0.050). In study conducted by S.S.Patil et al,[9] CI was better for VMAT than 3D CRT(0.72 vs 0.39). this is in contrast to our study.

In our study, there is better target coverage, better Homogeneity in VMAT plan compared to 3D CRT plan.CI was almost same for 3D CRT and VMAT. This is in contrast to other studies. The possible explanation could be VMAT is a relatively newer technique at our institution and experience of planning medical physicist in VMAT treatment planning is relatively less when compared to 3D CRT planning experience, this may result in a better 3D CRT plan than VMAT plan. The mean of MU was 380.15 (±91.6) and 403 (±35.7) for 3D CRT and VMAT plans respectively. The differences between the means was not statistically significant (p=0.27). MU was less for 3D CRT compared to 3D CRT but not significantly less.

In study conducted by Jimenez et al,[6] .MU was less for VMAT (558+-127) compared to 3D CRT (588+-98) p=0.499. It is in contrast to our study. In study conducted by Vivekanandan et al,[8] MU was more for VMAT (360.2+-42.07) compared to 3D CRT (246+_15.41) p value =0.006, significant. This is comparable to our study. In study conducted by S.S.Patil et al[9] MU are more for VMAT(460) compared to 3D CRT(231). This is comparable with our study.

The Mean of Spinal Cord D max difference n study groups was statistically significant. All VMAT plans complied with OAR constraint of <45 Gy. But in 3D CRT plan, D max was 46.1, little more than 45 Gy. but all 3D CRT plans achieved constraint of 0.3cc less than 50 Gy. There is a difference of 14.3gy between mean of D max for 3D CRT

and VMAT allowed maximum sparing of spinal cord (about 1 to 2%) in terms of the maximum dose. This is comparable with study conducted by Jimenez et al,[6] where in VMAT D max was 33.0+-4.1 and in 3D CRT, D max was 40.2±3.7. In study conducted by Vivekanandan et al,[8] the difference was not statistically significant, but spinal cord dose was less for VMAT.

All VMAT and 3D CRT plans was done with constraint of v45<67%. D mean of 30 Gy and V30 Gy <= 30 Gy was achieved with VMAT plans but not with 3D CRT plans. This may be because in 3D CRT plans, right and left posterolateral obliques are planned in order to spare spinal cord, these fields directly pass through Heart. Hence, Heart dose will be more in 3D CRT plan than VMAT plan.

The mean dose % of Heart difference was statistically significant. The median of mean dose % of Heart was 34.3 and 22.9 for 3D CRT and VMAT plans respectively. VMAT plans achieved much better D mean than 3D CRT plans. The difference was significant. The mean of V5% for Heart was 73.4 (±34.3) and 77.9 (±33) for 3D CRT and VMAT plans respectively. The differences in means of V5% was not significant (p=0.214).

The mean of V10% for Heart was 67.4 (±33.6) and 71.22 (±31.9) for 3D CRT and VMAT plans respectively. The differences in means of V10% was not significant (p=0.327). The mean of V15**%** for Heart was 64.6 (±32.7) and 56.27 (±26.1) for 3D CRT and VMAT plans respectively. The differences in means of V15% was not significant (p=0.07). The median of V15% was 76.8 and 64 for 3D CRT and VMAT plans respectively. The mean of V20**%** for Heart was 62.2 (±32.6) and 40.35 (±18.9) for 3D CRT and VMAT plans respectively. The differences in means of V20% was significant (p=0.002). The mean of V30**%** for Heart was 55.2 (±31) and 18.8 (±11.19) for 3D CRT and VMAT plans respectively. The differences in means of V30% was significant (p=003).

In study conducted by Jimenez et al,[6] V20 of Heart for 3D CRT was 49.8±23.2 and for VMAT 28.2±22.6.the difference was statistically significant. This is comparable to our study. In study conducted by Wu and Xie et al,[5] D mean of Heart was 29.4±9.9 for 3D CRT and for VMAT 22.64±8.7. the difference was significant(p=0.046). V30 46.8±22.6 and 27.9±12.6 for 3D CRT and VMAT respectively the difference was significant(p=0.007). This is comparable to our study.

In our study, D mean, V20 and V30 of Heart are better for VMAT plans compared to 3D CRT plans. The difference was statistically significant. But for V5, V10 and V15, the difference was not statistically significant. VMAT can reduce dose to Heart and reduce cardiological events significantly compared to 3D CRT.

All VMAT and 3D CRT plans was done achieving Lung constraints. The mean of D Mean % of Lung was 12.9 (±4.3) and 14.5 (±4.41) for 3D CRT and VMAT plans respectively. The difference between means was statistically significant (p = 0.008). D mean of Lung was better achieved with 3D CRT than VMAT. The mean of V5% of Lung was 66.9 (±19.1) and 78.8 (±21.4) for 3D CRT and VMAT plans respectively. The difference between means was statistically significant (p = .001). The median of V5% of Lung was 66.8 and 84.1 for 3D CRT and VMAT plans respectively. V5% was very better reduced with 3D CRT compared to VMAT.

The mean of V10% of Lung was 37.6 (±16.3) and 67 (±22) for 3D CRT and VMAT plans respectively. The difference between means was statistically significant (p = 003). The median of V10% of Lung was 35.2 and 66 for 3D CRT and VMAT plans respectively. V10% was much better reduced with 3D CRT than VMAT.

The mean of V15% of Lung was 24.6 (±13.4) and 43.1 (±19.6) for 3D CRT and VMAT plans respectively. The difference between means was statistically significant (p = 0). The median of V15% of Lung was 23.2 and 43.75 for 3D CRT and VMAT plans respectively. V15% was much better reduced with 3D CRT than VMAT.

The mean of V20% of Lung was 20.7 (±11.9) and 23.6 (±11.7) for 3D CRT and VMAT plans respectively. The difference between means was statistically not significant (p = 0.216). The median of V 20% of Lung was 19.02 and 22.8 for 3D CRT and VMAT plans respectively. The mean of V 30% of Lung was 14.35 (±5.68) and 7.22 (±3.8) for 3D CRT and VMAT plans respectively. The difference between means was statistically significant (p = 0). The median of V 30% of Lung was 14.85 and 7.25 for 3D CRT and VMAT plans respectively. V30% was much reduced r with VMAT compared to 3D CRT. The mean of V 40% of Lung was 9.9 (±4.11) and 2.97 (±1.56) for 3D CRT and VMAT plans respectively. The difference between means was statistically significant (p = 0). The median of V40% of Lung was 10.8 and 2.95 for 3D CRT and VMAT plans respectively. In the study conducted by Vivekanandan et al,[8] Lung D mean was 14.7±1.34 and 13.8±1.3 for 3D CRT and VMAT respectively. The difference was statistically significant(p=0.003). This is comparable with our study. V20 was 22.11± 7.6 and 13.8± 4.23 for 3D CRT and VMAT respectively the difference was statistically significant. This is in contrast with our study. V30 was 8.36±2.91 and 3.49± 1.64 for 3D CRT and VMAT respectively. The difference was statistically significant.

In the study conducted by Vivekanandan et al,[8] Lung D Mean was 14.7±1.34 and 13.8±1.3 for 3D CRT and VMAT respectively. The difference was statistically significant (p=0.003). This is comparable with our study. V5 was 47.9±6.1 and 80.8±14.9 for 3D CRT and VMAT respectively. The difference was statistically significant (p=0.003). The difference was statistically significant (p=0.001). This is comparable with our study. This is in contrast with our study with V30 was 13.2±3.3 and 8.8±3.3 for 3D CRT and VMAT respectively. The difference was

statistically significant.

In studies of Lung complications related to radiation dose, commonly reported parameters related to pulmonary toxicity was Lung V20 and mean Lung dose. The QUANTEC guideline showed 20% risk of RP for a mean Lung dose of 20 Gy. Kwa et al[10] evaluated the mean Lung dose in a multi-institutional study involving 540 patients. There was a report of RP with a mean Lung dose of 5% at 0–8 Gy, 11% at 8.1–16 Gy, 17% at 16.1–24 Gy, and 43% at 24.1–36 Gy. And Emami et al.[11] described the 5% incidence of symptomatic pneumonitis when Lung V5 was <42%. These results suggested that low-dose exposure in the Lung was associated with RP.

In this study V5, V10, V15 and D mean of Lung are higher for VMAT compared with 3D CRT so there is high risk of radiation pneumonitis in patients treated with VMAT than 3D CRT.V30 and V40 are reduced for Lung in VMAT compared with 3D CRT. So there sparing of Lung volumes at higher doses but Lung will receive low doses significantly when treated with VMAT resulting in radiation pneumonitis.

5. Limitations

Study findings could not be generalized, as it is a single institution study. Clinical importance of, and effects on clinical outcome i.e., tumour control and toxicity by, very small absolute difference in conformity index and other dosimetric parameters of target volume coverage, which are statistically significant, cannot be assessed, as the study is not planned and powasd for such assessment.

6. Conclusion

Theoretically, VMAT should produce better conformity of target volume than 3D CRT as it utilizes full gantry rotation. In this study it is observed that both 3D CRT plans and VMAT plans showed equally conformal. Homogeneity index was better for VMAT Plans compared with3D CRT. There is better target coverage with VMAT compared with 3D CRT. In this study Monitor Units are reduced for 3D CRT than VMAT (comparable with other studies). but p value was not significant. In this study Dose to spinal cord is significantly reduced with VMAT technique, when compared to 3D CRT, VMAT plans in this study showed significantly reduced doses to Heart, when compared to 3D CRT plans.

VMAT plans decrease volume of Lung receiving high dose(V20, Dmean,V30,V40) compared to 3D CRT but at a cost of delivering low dose to more volume of Lung (V5, V10, V15) resulting in serious complications like radiation pneumonitis.

By considering the above results, VMAT plans are advisable in carcinoma oesophagus patients to achieve reduced doses to OARs like Spinal Cord, Heart & Lung and better target coverage particularly in cervical oesophagus where higher doses are planned. Although VMAT provides better PTV coverage, homogeneity and dose reduction to Spinal Cord and Heart, it can only decrease volume of Lung and Heart receiving higher dose but at a cost of delivering low dose to more volume of Lung and as MUs are more for 3D CRT. In view of the above, 3D CRT is still a feasible option in high volume centre's such as our Institute. Need further evaluation by conducting more studies.

7. Source of Funding

None.

8. Conflict of interest

The authors declare that there are no potential conflicts of interest for the authorship and publication of the article.

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Cite this article: Ramakrishna M, Krishna K, Madhuri MSP. Dosimetric analysis of 3 dimensional conformal radiotherapy with volumetric modulated arc therapy in patients with carcinoma oesophagus – Prospective study. *Panacea J Med Sci* 2022;12(3):582-589.