# Intensity-Modulated Radiotherapy (IMRT) versus Volumetric Modulated Arc Therapy (VMAT) for Locally Advanced Non-Small Cell Lung Cancer

Ata RSE[1], Gad OA[1], El Sebaie MM[2], El-Kady AM[1]

[1] Clinical Oncology and Nuclear Medicine Department, Faculty of Medicine, Tanta University
[2] Clinical Radiation Oncology and Nuclear Medicine, National Cancer Institute, Cairo University

## Abstract:

**Background:** For stage III non-small cell lung cancer (NSCLC), current treatment is conventional radiotherapy, concurrently with platinum chemotherapy with or without induction chemotherapy, with consolidation durvalumab. Volumetric modulated arc therapy (VMAT) allows higher target conformity and homogeneity with less scatter dose due to reducing MU, causing fewer secondary malignancies and less treatment time.

**Aim**: Comparison between IMRT and VMAT in stage III NSCLC patients regarding dosimetric differences and clinical outcome including response, survival and toxicity and their correlation with clinicopathological characteristics.

**Methods**: This is a prospective randomized study using simple randomization by coin which included 60 patients with stage III NSCLC who received concurrent chemoradiation at Clinical Oncology and Nuclear Medicine Department Tanta University Hospitals comparing clinical outcome and correlation with clinicopathological characteristics and dosimetric parameters throughout the period from July 2021 to June 2023. Thirty patients received IMRT (Group A) and 30 received VMAT (Group B).

**Results**: There was no significant difference in dosimetric parameters except for contralateral mean dose and esophageal parameters without effect on toxicity. The main significant difference was shorter delivery time and less monitor units in VMAT group. There was no significant difference in response. Progression free survival was significantly higher in VMAT with significant correlation to grade and mean esophageal dose.

**Conclusion**: The VMAT provides shorter delivery time and less monitor units with less treatment cost. Both IMRT and VMAT are similar in toxicity. Progression free survival is higher in VMAT with similar treatment response.

**Keywords**: Lung cancer, chemoradiation, arc therapy, IMRT, and toxicity

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**Authors Information:**

*Rana Saeed El-Sayed Ata*
Clinical Oncology and Nuclear Medicine Department, Faculty of Medicine, Tanta university
email: roomed2015@gmail.com
rana.saeed@med.tanta.edu.eg

*Omnia Abd El Fattah Gad,*
Clinical Oncology and Nuclear Medicine Department, Faculty of Medicine, Tanta University
email: omniaabdelfattah@yahoo.com
omnia.gad@med.tanta.edu.eg

*Medhat Mohamed El Sebaie*
Clinical Radiation Oncology and Nuclear Medicine, National Cancer Institute, Cairo University
email: melsebaie@gmail.com

*Asmaa Mohamed El-Kady*
Clinical Oncology and Nuclear Medicine Department, Faculty of Medicine, Tanta University
email: Asmaa_mohamed_e@hotmail.com
asmaa.elkadi@med.tanta.edu.eg

**Corresponding Author:**
*Rana Saeed El-Sayed Ata*
Clinical Oncology and Nuclear Medicine Department, Faculty of Medicine, Tanta university
email: roomed2015@gmail.com
rana.saeed@med.tanta.edu.eg

## Background:

Lung cancer represents the most common (12.4%) and the most fatal cancer (18.7%). In Egypt, it represents the fifth most common cancer (5.1%) and the fourth most fatal one (7.1%). It ranks the third in males, ninth in females and the 5th in both sexes [1].

Approximately 35% of all NSCLC patients diagnosed have stage III tumors [2]. The standard of treatment for non-progressing inoperable stage III NSCLC has shifted from sequential to concurrent platinum-based chemotherapy and radiation, often known as chemoradiotherapy (CRT) followed by consolidation durvalumab [3].

The IMRT, VMAT and Proton therapy are developments over 3DCRT to reduce radiation exposure to healthy tissues while increasing conformal dosage to the target [4]. Volumetric modulated arc therapy is proved as a novel technology with freedom of selection of number of arcs making it more efficient and faster in treatment time and monitor units (MUs) delivery. The risk of secondary malignancy in VMAT should be lower as it uses fewer monitor units (MU) compared with conventional fixed field IMRT [5].

***Aim:***

Comparison between IMRT and VMAT in stage III NSCLC patients regarding dosimetric differences and clinical outcome including response, survival and toxicity and their correlation with clinicopathological characteristics.

## Patients and Methods:

This is a prospective randomized study which included 60 patients with stage III NSCLC who received concurrent CRT at Clinical Oncology and Nuclear Medicine Department Tanta University Hospitals evaluating and comparing clinical outcome and correlating them with clinicopathological characteristics and dosimetric parameters throughout the period from July 2021 to June 2023. Thirty patients received IMRT (Group A) and 30 received VMAT (Group B). The patients aged more than 18 years old with performance status 0 to 2 according to ECOG (Eastern Cooperative Oncology Group) score with adequate organs' functions diagnosed with locally advanced histopathologically, radiologically proved stage III NSCLC according to 8th edition AJCC TNM (American Joint Committee on Cancer) staging treated with concurrent CRT IMRT or VMAT with radiation dose 54-66.6 Gy. Dose reduction to 54 – 60 Gy was allowed if the OARs were not meeting constraints. The dose-volume constraints were set as follows for optimization: lungs (V20 ≤ 35%) (When the V20 Gy exceeded 35%, it could be decided to accept it, or consider reducing the margin, or the prescribed dose), mean lungs

dose (MLD ≤ 20 Gy). The maximum dose administered of the spinal cord was 45 Gy and spinal cord PRV was 50 Gy. The esophagus PRV dose was kept at 55 Gy (V55) to 30% of the organ volume and the heart (V40) to 50% of the organ volume [6].

*Exclusion criteria* were Patients with performance status more than 2 or with other malignancy.

Clinicopathological features of tumors and patients were gathered. They were subjected to accurate diagnosis and proper staging through complete history and diagnostic work-up including laboratory tests, respiratory function tests (FEV1), imaging Studies and biopsy. Informed consent was obtained from all patients after full explanation of benefits and risks of treatment.

All patients received 4 cycles of induction chemotherapy with carboplatin (AUC=6) and paclitaxel (200 mg/m²) every three weeks. Both groups of patients received concurrent chemotherapy, which included weekly intravenous dosing of carboplatin with an AUC of 2 and 45 mg/m² of paclitaxel.

All patients were treated with CRT as follows: Group A: included 30 patients treated with IMRT with dose ranging from 54 to 66 Gy in 27 to 33 fractions, 2 Gy per fraction, daily five days a week within 7 weeks, four patients received 54 Gy, 11 patients received 66 GY, 15 received 60 Gy. Group B: included 30 patients treated with VMAT with dose ranging from 60 to 66.6 Gy in 30 to 37 fractions, 1.8 to 2 Gy per fraction, daily five days a week within 7 weeks. Seven patients received 60 Gy, 21 received 66 Gy and 2 patients received 66.6 Gy.

Primary tumour and lymph nodes that were considered suspicious or confirmed by histopathology were included in the gross tumour volume (GTV). A clinical target volume (CTV) was defined as an area that included the main tumour and lymph nodes within a margin of 5–15 mm (6 mm in squamous NSCLC, 8 mm in adenocarcinoma), as well as positive lymph node stations in the mediastinum. Following a 5-10 mm extension of the CTVs, the planning target volume (PTV) was generated. The ITV was generated to compensate for respiratory motion in inspiration and expiration.

The organs at-risk (OARs) included: spinal cord, esophagus, heart, lungs (ipsilateral and contralateral), total lung (lung all-PTV), which is consistent with the international ESTRO ACROP guideline. The dose-volume constraints were set for optimization.

The dose prescribed to PTV ranged from 54 to 66.6 Gy in 27 to 37 fractions, 1.8 to 2 Gy per fraction using 6 MV photons, given on a once daily basis 5 days a week within 7 weeks using IMRT or VMAT. In group A, 4 patients received 54 Gy, 11 patients received 66 Gy, 15 received 60 Gy. In group B, 7 patients received 60 Gy, 21 received 66 Gy and 2 patients received 66.6 Gy depending on tumour location and size to meet OARs constraints.

Treatment planning was conducted using the Eclipse 13.7 treatment planning system from Varian. Depending on the tumor's location, each IMRT plan used 5 to 9 coplanar beams. For VMAT plan optimization, single (full) or partial arc (PA) or two partial arc (2 PA) VMAT plans were generated according to target volume and dosimetric considerations. Eighteen patients in group B plans were by single arc, 8 plans with 1 partial arc and 4 plans with 2 partial arcs.

The treatment delivery time and MUs were recorded and evaluated. Additional data on radiation planning parameters were extracted from the departmental radiation oncology information management system (ARIA, Varian Medical Systems). Treatment gaps ranged from one to 4 days in 3 patients due to grade 2 esophagitis in 2 patients and grade 3 pneumonitis in 1 patient which was compensated if needed with compensatory fractions.

*Plan evaluation:*

Dose volume histograms (DVHs) and the dose distributions were assessed. The PTV coverage was assessed using Dmax, Dmin, Dmean, the heterogeneity index (HI), and the conformance index (CI). The coverage of PTV was set to at least 95% of the PTV volume covered by the 95% prescribed dose, minimizing volume receiving >115% of prescribed dose to <1%.

The evaluation criteria of OARs were defined basically according to RTOG 1106. The following

dosimetric data were collected: PTV Dmax, Dmin, Dmean (Gy), PTV volume (cm3), total lung minus PTV, V5 Gy (%),V20 Gy (%) and mean lungs dose (Gy), contralateral lung V5 Gy (%),V20 Gy (%) and mean lung dose (Gy), ipsilateral lung V5 Gy (%),V20 Gy (%) and mean lungs dose (Gy), esophagus V55 Gy (%), mean dose (Gy), heart V10 (%), V40 (%) and mean heart dose (Gy), Dmax of spinal cord. Differences between the IMRT and VMAT groups were evaluated statistically.

*Follow-up:*

During treatment, patients were evaluated weekly during CRT and after end of treatment, patients were followed up every 3 months by history, clinical examinations, CT chest, abdomen up to two years. Median follow up was 17.5, 17.5 and 16.5 months for all patients, IMRT and VMAT groups respectively.

*Assessment of tumour response:*

It was performed four weeks after the end of chemotherapy using CT chest or FDG-PET CT scan according to Response Evaluation Criteria in Solid Tumors, version 1.1 (RECIST 1.1) guidelines.

*Assessment of toxicity:*

Acute toxicity (up to 3 months post-treatment) and late toxicity (beyond 3 months) from the CRT were assessed and graded based on common terminology criteria for adverse events (CTCAE) version 5.0.

*Assessment of survival*

Progression free survival (PFS) was calculated from the start of treatment to the date of disease progression or death.

*Statistical analysis:*

Enrollment of patients started in July 2021, ended in June 2023. The date of final analysis was in December 2023. The collected data were organized and statistically analyzed using SPSS software version 25. P value was used to indicate the level of significance $\leq$ 0.05 is significant and < 0.001 is highly significant. The PFS survival plots were estimated using Kaplan-Meier method and the Cox proportional hazards model was used for multivariate analysis.

## Results:

In group A, the mean age was 62 years, while in group B, mean age 63.3 years. Most patients in both groups were males and were of performance 1. Most patients in both groups were current or ex-smokers. Both groups predominantly included adenocarcinoma and grade 2. About 33%, 43% of patients in group A, B had wild EGFR. According to stage, stage IIIB represented the most common stage in both groups. Most patients had T4 and N2 tumors in both groups. Group A included mainly left sided tumors while group B included mainly right sided tumors which was statistically significant. Most patients in group A had central tumours (60%) versus peripheral tumours in group B (70%) which was statistically significant. According to pretreatment respiratory function via forced expiratory volume 1 (FEV1) z score, most patients in both groups had mild obstruction with z score between -1.65 to -2.5.

The detailed distribution of dosimetric parameters for PTV is shown in table 2. Median PTV volume in group A was 401.9 cm3 while in group B median PTV volume was 778.4 cm3 with p value = 0.051. Mean dose in IMRT group was 61.4 Gy vs 64.6 Gy with significant p value<0.001. There was a statistically significant difference between both groups as regard D50. As regards conformity index, median CI in IMRT group (A) was 0.66 vs 0.64 in VMAT group while heterogeneity index was 0.099 vs 0.15 in group A, B respectively with statistical significance. The Dmean was higher in VMAT (64.3 vs 61.6 Gy, p=0.005).

Table 3 shows differences between both groups according to organs at risk dosimetric parameters. Ipsilateral lung V5 and V20 was higher in VMAT while MLD was higher in group A with no statistical significance. Contralateral lung V5, 20 and MLD was higher in IMRT. According to both lungs' parameters, V5 was almost equal in both groups while V20 was higher in group B and MLD was higher group A with non-significant p value. Heart received lower doses in VMAT, but these differences were not statistically significant. Mean dose and V55 of esophagus were higher in VMAT with significant p value 0.043, <0.001 respectively). As illustrated, Dmax of spinal cord was lower in group B which was not statistically significant.

As regards treatment delivery parameters as shown in table 4, median delivery time was significantly shorter in VMAT (9 vs 18 minutes) with p value <0.001. Monitor units were higher in IMRT (1565 vs 459 MUs) with p value (p <0.001).

*Response*

According to response as shown in figure 1, group A had higher overall response with p value = 0.598. Complete response (CR) was achieved in about 3% of patients in each of the two groups.

Univariate analysis showed significant relation between response and smoking, stage, Dmax, Dmean and total dose, while in multivariate analysis, it was significant with smoking and stage as shown in table 4.

*Progression free survival (PFS)*

In IMRT group, median follow up was 17.5 months and median progression free survival (PFS) was 10 months while in VMAT group, median follow up was 16.5 months and median PFS was 15 months which was statistically significant (p = 0.008). At 6 months, PFS was 66.7% in IMRT group vs 83.3% in VMAT group as shown in figure 2.

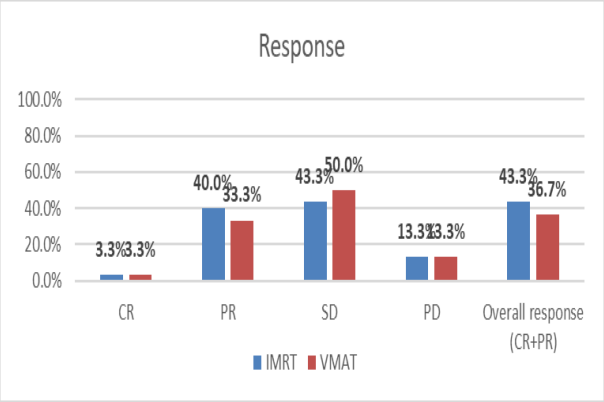


Figure 1: Comparison of treatment response between both groups

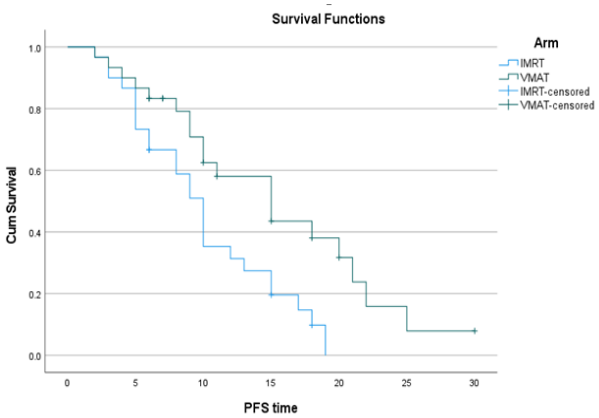


Figure 2: Progression free survival (PFS) curve

Table 5 illustrates that in univariate analysis of PFS prediction in total population was significantly related to grade, both lungs MLD and mean esophageal dose, while in multivariate analysis, it was significantly related to grade and mean esophageal dose only.

*Toxicity*

Regarding CRT toxicity shown in table 4, grade ≥ 2 pneumonitis was higher in group B (33%) vs 30% in group A, but it was not statistically significant. Grade 2 or more esophagitis was higher in group B with no statistically significant difference.

As shown in table 7, Grade 2 or more pneumonitis was more experienced in VMAT, males, aged more than 60 years, smokers or ex-smokers, right-sided tumours and worse PS with no statistical significance. While it was more found in stage IIIB, higher lungs parameters which was statistically significant except contralateral lung V20.

Univariate analysis of grade ≥2 pneumonitis in total population revealed statistically significant correlation with ipsilateral lung, contralateral lung and both lungs' parameters and PTV volume which were all not significant in multivariate analysis as shown in table 8.

As shown in table 9, Grade 2 or more esophagitis was more experienced in VMAT, males, aged more than 60 years, smokers or ex-smokers, right-sided tumours and worse PS and stage IIIb with no statistical significance. While it was significant with higher esophageal V55 and esophageal mean dose.

As shown in table 10, In univariate analysis of grade ≥2 esophagitis in all patients, it was significantly higher in higher esophageal V55, mean esophageal dose, while in multivariate analysis, it was only related to esophageal mean dose with significant P value 0.01.

*Case*

A 60-year-old male patient, PS 0, no comorbidity, non-smoker, with left peripheral, hilar bronchogenic squamous cell carcinoma grade II EGFR wild, stage IIIA T2aN2M0, treated with a full arc plan to 66 Gy, delivery time was 9 minutes using 488 MUs, PTV volume was 1141.4 $cm^3$, with CI 0.51, HI 0.28, achieved radiological CR after CCRT with no more than grade I toxicity.

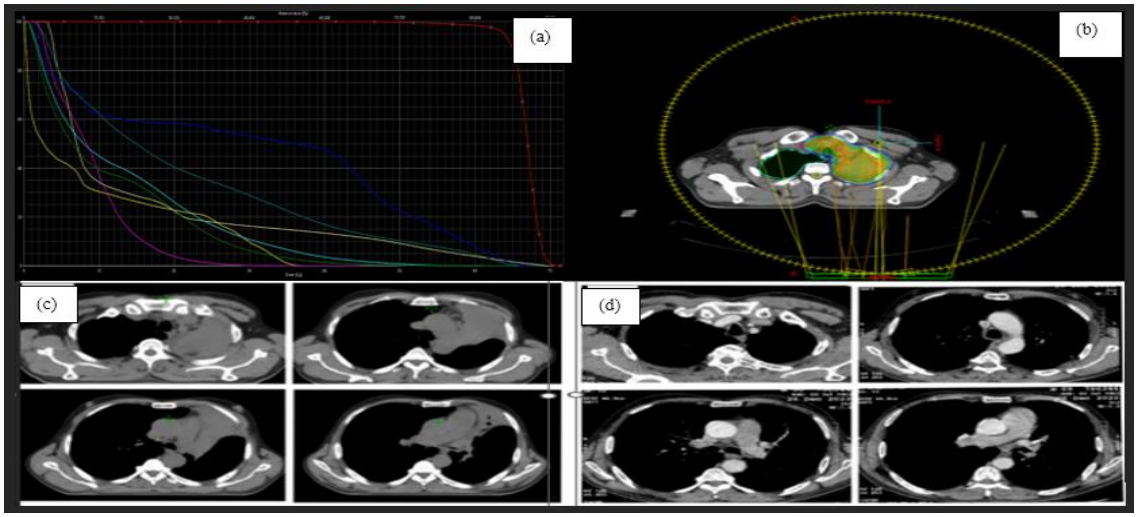


Figure 3: Dose volume histogram (DVH) (a) and Dose colour wash, field arrangement (b) and Pre-CRT (c) and post-CRT (d) axial CT slices

Table (1): Clinicopathological characteristics of patients

| | Group A IMRT (n=30) | | Group B VMAT (n=30) | | P |
|---|---|---|---|---|---|
| | No. | % | No. | % | |
| Sex | | | | | 1.00 |
| Male | 26 | 86.7 | 25 | 83.3 | |
| Female | 4 | 13.3 | 5 | 16.7 | |
| Age | | | | | 0.647 |
| Mean ± SD. | 61.9 ± 13.12 | | 63.3 ± 8.88 | | |
| Range | 20.0 – 82.0 | | 46.0 – 83.0 | | |
| PS | | | | | 0.842 |
| 0 | 12 | 40.0 | 14 | 46.7 | |
| 1 | 16 | 53.3 | 15 | 50.0 | |
| 2 | 2 | 6.7 | 1 | 3.3 | |
| Comorbidity | | | | | |
| DM | 5 | 16.7 | 4 | 13.3 | 1.00 |
| HTN | 4 | 13.3 | 3 | 10.0 | 1.00 |
| Cardiac | 2 | 6.7 | 0 | 0.0 | 0.492 |
| Hypothyroidism | 0 | 0.0 | 1 | 3.3 | 1.00 |
| Smoking | | | | | 0.257 |
| No | 7 | 23.3 | 13 | 43.3 | |
| Yes | 13 | 43.3 | 10 | 33.3 | |
| Ex-smoker | 10 | 33.3 | 7 | 23.3 | |
| Pathology | | | | | 0.643 |
| Adenocarcinoma | 24 | 80.0 | 21 | 70.0 | |
| Squamous | 5 | 16.7 | 7 | 23.3 | |
| Undifferentiated | 1 | 3.3 | 2 | 6.7 | |
| Grade | | | | | 0.519 |
| 2 | 25 | 83.3 | 23 | 76.7 | |
| 3 | 5 | 16.7 | 7 | 23.3 | |
| EGFR | | | | | 1.00 |
| Wild | 10 | 33.3 | 13 | 43.3 | |
| Mutant | 2 | 6.7 | 2 | 6.7 | |
| Unknown | 18 | 60 | 15 | 50 | |
| Stage | | | | | 0.591 |
| IIIA | 8 | 26.7 | 10 | 33.3 | |
| IIIB | 20 | 66.7 | 16 | 53.3 | |
| IIIC | 2 | 6.7 | 4 | 13.3 | |
| T stage | | | | | 0.797 |
| T1c | 1 | 3.3 | 1 | 3.3 | |
| T2 | 3 | 10.0 | 3 | 10.0 | |
| T3 | 12 | 40.0 | 8 | 26.7 | |
| T4 | 14 | 46.7 | 18 | 60.0 | |
| N stage | | | | | 0.567 |
| N0 | 3 | 10.0 | 5 | 16.7 | |
| N1 | 1 | 3.3 | 2 | 6.7 | |
| N2 | 24 | 80.0 | 19 | 63.3 | |
| N3 | 2 | 6.7 | 4 | 13.3 | |
| Side | | | | | 0.008 |
| Rt | 13 | 43.3 | 23 | 76.7 | |
| Lt | 17 | 56.7 | 7 | 23.3 | |
| Location | | | | | 0.020 |
| Peripheral | 12 | 40.0 | 21 | 70.0 | |
| Central | 18 | 60.0 | 9 | 30.0 | |
| FEV1 (z-score) | | | | | 0.225 |
| < -1.65 | 7 | 23.3 | 12 | 40.0 | |
| -1.65 to -2.5 | 13 | 43.3 | 13 | 43.3 | |
| -2.5 to -4 | 10 | 33.3 | 5 | 16.7 | |

Data are presented as mean ± SD or frequency (%).PS: Performance status, DM: diabetes mellitus, HTN: hypertension, Rt: right, Lt left

Table 2: Dosimetric (PTV parameters) comparison between groups

| | IMRT (n=30) | VMAT (n=30) | p |
|---|---|---|---|
| PTV volume | | | 0.051 |
| Median (IQR) | 401.9 (210.725 – 1010.5) | 778.4 (644.475 – 879.575) | |
| Dose | | | <0.001 |
| Mean ± SD. | 61.4 ± 4.07 | 64.6 ± 2.61 | |
| Range | 54.0 – 66.0 | 60.0 – 66.6 | |
| D2 | | | <0.001 |
| Mean ± SD. | 64.2 ± 3.70 | 67.8 ± 3.02 | |
| Range | 58.18 – 70.94 | 62.88 – 77.12 | |
| D98 | | | 0.805 |
| Mean ± SD. | 57.4 ± 4.53 | 57.7 ± 4.36 | |
| Range | 49.37 – 65.44 | 49.02 – 66.26 | |
| D50 | | | 0.005 |
| Mean ± SD. | 61.8 ± 4.07 | 64.6 ± 3.28 | |
| Range | 53.70 – 68.86 | 59.17 – 73.86 | |
| Conformity index | | | 0.193 |
| Median (IQR) | 0.655 (0.5375 – 0.7925) | 0.635 (0.51 – 0.685) | |
| Heterogeneity index | | | <0.001 |
| Median (IQR) | 0.099 (0.0737 – 0.128) | 0.15 (0.118 – 0.188) | |
| Dmax | | | <0.001 |
| Mean ± SD. | 65.7 ± 4.23 | 71.1 ± 3.28 | |
| Range | 56.59 – 73.17 | 65.25 – 79.67 | |
| Dmin | | | 0.224 |
| Mean ± SD. | 51.0 ± 6.62 | 48.8 ± 7.45 | |
| Range | 27.5 – 61.09 | 21.8 – 59.59 | |
| Dmean | | | 0.005 |
| Mean ± SD. | 61.6 ± 4.03 | 64.3 ± 3.16 | |
| Range | 54.1 – 68.62 | 58.57 – 73.29 | |

Data are presented as median, mean ± SD or frequency (%). PTV: planning target volume, IQR: interquartile range

Table (3): Dosimetric (OARs parameters) comparison between groups

| | IMRT (n=30)<br>Median (IQR) | ` | p |
|---|---|---|---|
| Ipsilateral lung | | | |
| V5 | 67.265 (47.57 – 82.54) | 70.92 (65.19 – 86.64) | 0.068 |
| V20 | 40.88 (19.19 – 57.585) | 45.865 (44.41 – 56.51) | 0.089 |
| MLD | 27.64 (18.69 – 31.48) | 23.61 (22.55 – 30.905) | 0.802 |
| Contralateral lung | | | |
| V5 | 61.39 (37.08 – 77.01) | 58.285 (47.1 – 75.047) | 0.723 |
| V20 | 21.67 (1.00 – 29.26) | 14.94 (8.535 – 24.325) | 0.657 |
| MLD | 17.97 (10.655 – 23.08) | 13.075 (8.99 – 17.3) | 0.014 |
| Both lungs | | | |
| V5 | 61.425 (42.615 – 75.18) | 61.0 (52.025 – 79.012) | 0.647 |
| V20 | 26.635 (8.807 – 33.485) | 29.695 (20.63 – 33.42) | 0.337 |
| MD | 20.3 (15.88 – 24.39) | 16.485 (11.767 – 20.55) | 0.107 |
| Heart | | | |
| V10 | 37.34 (2.0 – 67.255) | 28.75 (14.77 – 54.225) | 0.579 |
| V40 | 3.365 (0.0 – 7.407) | 2.215 (1.225 – 7.99) | 0.699 |
| MHD | 17.31 (7.767 – 22.967) | 9.115 (5.587 – 21.67) | 0.067 |
| Esophagus | | | |
| V55 | 0.07 (0.0 – 5.565) | 20.645 (11.895 – 27.40) | <0.001 |
| Mean | 29.19 (19.73 – 32.05) | 31.255 (28.35 – 33.027) | 0.043 |
| Spinal cord | | | |
| Dmax | 43.145 (34.187 – 44.145) | 42.09 (39.985 – 43.31) | 0.813 |

Data are presented as median, IQR. MLD: mean lung dose, IQR: interquartile range

Table 4: Univariate and multivariate analysis of response in total population

| | Univariate | | Multivariate | |
|---|---|---|---|---|
| | p | B (95%C. I) | p | B (95%C. I) |
| Smoking | 0.038* | -0.168 (-0.010 – 0.326) | 0.014* | -0.197 (0.042 – 0.352) |
| Pathology | 0.306 | -0.118 (-0.347 – 0.111) | | |
| Grade | 0.243 | -0.188 (-0.506 – 0.131) | | |
| EGFR | 0.144 | 0.375 (-0.132 – 0.882) | | |
| Stage | 0.022* | -0.241 (-0.446 - -0.036) | 0.025* | -0.215 (-0.403 - -0.028) |
| T stage | 0.115 | -0.127 (-0.285 – 0.032) | | |
| N stage | 0.117 | -0.126 (-0.284 – 0.032) | | |
| PTV volume | 0.726 | -0.00006 (-0.00007 – 0.0) | | |
| CI | 0.095 | 0.556 (-0.099 – 1.211) | | |
| HI | 0.127 | -1.543 (-3.537 – 0.452) | | |
| D max | 0.022* | 0.032 (0.005 – 0.059) | 0.688 | 0.013 (-0.079 – 0.052) |
| D min | 0.155 | 0.013 (-0.005 – 0.031) | | |
| D mean | 0.002* | 0.051 (0.020 – 0.082) | 0.281 | 0.043 (-0.036 – 0.122) |
| Dose | 0.003* | 0.050 (0.018 – 0.082) | 0.476 | 0.023 (-0.041 – 0.087) |
| Technique | 0.605 | -0.067 (-0.324 – 0.19) | | |

Data are presented as regression coefficient (B) and 95% confidence interval (C.I), EGFR: epidermal growth factor receptor, PTV: planning target volume, CI: conformity index, HI: heterogeneity index

Table 5: Univariate and multivariate analysis of PFS in total population

| | Univariate | | Multivariate | |
|---|---|---|---|---|
| | p | B (95%C. I) | p | B (95%C. I) |
| Age | 0.877 | -0.011 (-0.136 – 0.158) | | |
| PS | 0.273 | -1.531 (-4.299 – 1.238) | | |
| Smoking | 0.481 | -0.730 (-2.792 – 1.332) | | |
| Pathology | 0.470 | -1.054 (-3.955 – 1.847) | | |
| Grade | 0.046* | -4.0 (-7.918 - -0.082) | 0.017* | -4.441 (-8.072 - -0.809) |
| EGFR | 0.241 | 3.804 (-2.624 – 10.231) | | |
| Stage | 0.152 | -1.926 (-4.582 – 0.731) | | |
| T stage | 0.284 | -1.091 (-3.112 – 0.929) | | |
| N stage | 0.148 | -1.464 (-3.461 – 0.533) | | |
| FEV1 | 0.457 | -0.806 (-2.96 – 1.347) | | |
| PTV volume | 0.671 | -0.001 (-0.005 – 0.003) | | |
| Dose | 0.069 | 0.391 (-0.031 – 0.813) | | |
| OAR | 0.067 | 3.0 (-0.217 – 6.217) | | |
| Pneumonitis | 0.243 | -1.026 (-2.765 – 0.714) | | |
| Cardiac toxicity | 0.903 | 0.196 (-3.014 – 3.405) | | |
| Heart MHD | 0.093 | -0.155 (-0.337 – 0.026) | | |
| Both lungs MLD | 0.050* | -0.233 (-0.466 – 0.0) | 0.112 | -0.177 (-0.397 – 0.043) |
| Both lungs V5 | 0.646 | -0.017 (-0.092 – 0.057) | | |
| Esophagus V55 | 0.008* | -0.186 (-0.050 – 0.322) | 0.010* | -0.177 (-0.045 – 0.310) |
| Esophagus mean | 0.931 | 0.010 (-0.210 – 0.229) | | |
| Technique | 0.074 | 2.867 (-0.290 – 6.023) | | |

Data are presented as regression coefficient (B) and 95% confidence interval (C.I), PS: performance status, EGFR: epidermal growth factor receptor, FEV1: forced expiratory volume, PTV: planning target volume, MLD: mean lung dose, MHD: mean heart dose

Table 6: Chemoradiation toxicity grading in both groups

| Toxicity (Grades) | IMRT (n=30) | | VMAT (n=30) | | p |
|---|---|---|---|---|---|
| | No. | % | No. | % | |
| Pneumonitis | | | | | 0.419 |
| Grade 0 | 14 | 46.7 | 17 | 56.7 | |
| Grade 1 | 7 | 23.3 | 3 | 10.0 | |
| Grade 2 | 9 | 30.0 | 9 | 30.0 | |
| Grade ≥ 3 | 0 | 0.0 | 1 | 3.3 | |
| Cardiac toxicity | | | | | 0.984 |
| Grade 0 | 20 | 66.6 | 24 | 80 | |
| Grade 1 | 2 | 6.7 | 1 | 3.3 | |
| Grade 2 | 0 | 0 | 0 | 0.0 | |
| Missing | 8 | 26.7 | 5 | 16.7 | |
| Esophagitis | | | | | 0.684 |
| Grade 0 | 11 | 36.7 | 10 | 33.3 | |
| Grade 1 | 12 | 40.0 | 10 | 33.3 | |
| Grade 2 | 7 | 23.3 | 10 | 33.3 | |
| Mucositis | | | | | 0.697 |
| Grade 0 | 11 | 36.7 | 10 | 33.3 | |
| Grade 1 | 11 | 36.7 | 9 | 30.0 | |
| Grade 2 | 8 | 26.7 | 11 | 36.7 | |
| Anemia | | | | | 0.710 |
| Grade 0 | 6 | 20.0 | 5 | 16.7 | |
| Grade 1 | 20 | 66.7 | 23 | 76.7 | |
| Grade 2 | 4 | 13.3 | 2 | 6.7 | |
| Neutropenia | | | | | 0.284 |
| Grade 0 | 10 | 33.3 | 16 | 53.3 | |
| Grade 1 | 14 | 46.7 | 11 | 36.7 | |
| Grade 2 | 6 | 20.0 | 3 | 10.0 | |
| Thrombocytopenia | | | | | 0.478 |
| Grade 0 | 24 | 80.0 | 26 | 86.7 | |
| Grade 1 | 6 | 20.0 | 3 | 10.0 | |
| Grade 2 | 0 | 0.0 | 1 | 3.3 | |
| Peripheral neuropathy | | | | | 0.34 |
| Grade 0 | 17 | 56.7 | 13 | 43.3 | |
| Grade 1 | 7 | 23.3 | 15 | 50.0 | |
| Grade 2 | 6 | 20.0 | 1 | 3.3 | |
| Grade 3 | 0 | 0 | 1 | 3.3 | |
| Hepatotoxicity | | | | | 1.00 |
| Grade 0 | 27 | 90.0 | 26 | 86.7 | |
| Grade 1 | 3 | 10.0 | 4 | 13.3 | |
| Vomiting | | | | | 1.00 |
| Grade 0 | 21 | 70.0 | 21 | 70.0 | |
| Grade 1 | 8 | 26.7 | 7 | 23.3 | |
| Grade 2 | 1 | 3.3 | 2 | 6.7 | |

Data are presented as frequency (%)

Table 7: Correlation between pneumonitis and with clinicopathological characteristics

| | Pneumonitis Grade | | |
|---|---|---|---|
| Characteristic | ≤1, (N = 41) | ≥2, (N = 19) | p-value |
| Arm, No. (%) | | | 0.781 |
| *IMRT* | 21.0 (51.2%) | 9.0 (47.4%) | |
| *VMAT* | 20.0 (48.8%) | 10.0 (52.6%) | |
| Age groups, No. (%) | | | 0.682 |
| *≤ 60* | 15.0 (36.6%) | 8.0 (42.1%) | |
| *> 60* | 26.0 (63.4%) | 11.0 (57.9%) | |
| Sex, No. (%) | | | 1.000 |
| *Female* | 6.0 (14.6%) | 3.0 (15.8%) | |
| *Male* | 35.0 (85.4%) | 16.0 (84.2%) | |
| Smoking, No. (%) | | | 0.924 |
| *Non-smoker* | 13.0 (31.7%) | 7.0 (36.8%) | |
| *Ex-smoker* | 12.0 (29.3%) | 5.0 (26.3%) | |
| *Smoker* | 16.0 (39.0%) | 7.0 (36.8%) | |
| DM, No. (%) | | | 0.705 |
| *No* | 34.0 (82.9%) | 17.0 (89.5%) | |
| *Yes* | 7.0 (17.1%) | 2.0 (10.5%) | |
| HTN, No. (%) | | | 0.414 |
| *No* | 35.0 (85.4%) | 18.0 (94.7%) | |
| *Yes* | 6.0 (14.6%) | 1.0 (5.3%) | |
| Stage, No. (%) | | | 0.009 |
| *IIIA* | 17.0 (41.5%) | 1.0 (5.3%) | |
| *IIIB* | 20.0 (48.8%) | 16.0 (84.2%) | |
| *IIIC* | 4.0 (9.8%) | 2.0 (10.5%) | |
| Side, No. (%) | | | 0.734 |
| *Right* | 24.0 (58.5%) | 12.0 (63.2%) | |
| *Left* | 17.0 (41.5%) | 7.0 (36.8%) | |
| PS, No. (%) | | | 0.815 |
| *0* | 17.0 (41.5%) | 9.0 (47.4%) | |
| *1* | 22.0 (53.7%) | 9.0 (47.4%) | |
| *2* | 2.0 (4.9%) | 1.0 (5.3%) | |
| FEV, No. (%) | | | 1.000 |
| *> -1.65* | 13.0 (31.7%) | 6.0 (31.6%) | |
| *-1.65 to -2.5* | 18.0 (43.9%) | 8.0 (42.1%) | |
| *-2.5 to -4* | 10.0 (24.4%) | 5.0 (26.3%) | |
| Ipsilateral lungV5, No. (%) | | | <0.001 |
| *≤69* | 29.0 (70.7%) | 1.0 (5.3%) | |
| *>69* | 12.0 (29.3%) | 18.0 (94.7%) | |
| Ipsilateral lungV20, No. (%) | | | <0.001 |
| *≤46* | 31.0 (75.6%) | 2.0 (10.5%) | |
| *>46* | 10.0 (24.4%) | 17.0 (89.5%) | |
| Ipsilateral lung MLD, No. (%) | | | 0.001 |
| *≤24* | 27.0 (65.9%) | 4.0 (21.1%) | |
| *>24* | 14.0 (34.1%) | 15.0 (78.9%) | |
| Contralateral lungV5, No. (%) | | | <0.001 |
| *≤61* | 30.0 (73.2%) | 0.0 (0.0%) | |
| *>61* | 11.0 (26.8%) | 19.0 (100.0%) | |
| Contralateral lungV20, No. (%) | | | 0.405 |
| *≤19* | 22.0 (53.7%) | 8.0 (42.1%) | |
| *<19* | 19.0 (46.3%) | 11.0 (57.9%) | |
| Contralateral lung MLD, No. (%) | | | <0.001 |
| *≤16* | 30.0 (73.2%) | 2.0 (10.5%) | |
| *>16* | 11.0 (26.8%) | 17.0 (89.5%) | |
| Both lungsV5, No. (%) | | | <0.001 |
| *≤61* | 29.0 (70.7%) | 0.0 (0.0%) | |
| *>61* | 12.0 (29.3%) | 19.0 (100.0%) | |
| Both lungsV20, No. (%) | | | <0.001 |
| *≤28* | 29.0 (70.7%) | 1.0 (5.3%) | |
| *>28* | 12.0 (29.3%) | 18.0 (94.7%) | |
| Both lungs MLD, No. (%) | | | <0.001 |
| *≤19* | 30.0 (73.2%) | 2.0 (10.5%) | |
| *>19* | 11.0 (26.8%) | 17.0 (89.5%) | |

Data are presented as frequency (%), IMRT: intensity modulated radiotherapy, VMAT: volumetric modulated radiotherapy, DM: diabetes mellitus, HTN: hypertension, PS: performance status, FEV: forced expiratory volume, MLD: mean lung dose

Table 8: Univariate and Multivariate analysis of for prediction of ≥ grade 2 pneumonitis

| | Univariate | | Multivariate | |
|---|---|---|---|---|
| | p | B (95%C. I) | p | B (95%C. I) |
| Smoking | 0.716 | 0.028 (-0.184 – 0.127) | | |
| FEV1 | 0.923 | 0.008 (-0.155 – 0.171) | | |
| Stage | 0.11 | 0.012 (-0.02-0.021) | | |
| Ipsilateral lung V5 | <0.001* | 0.014 (0.009 – 0.018) | 0.329 | 0.011 (-0.032 – 0.014) |
| Ipsilateral lung V20 | <0.001* | 0.015 (0.011 – 0.020) | 0.066 | 0.010 (-0.001 – 0.020) |
| Ipsilateral lung MLD | <0.001* | 0.036 (0.022 – 0.049) | 0.342 | 0.016 (-0.051 – 0.018) |
| Contralateral lung V5 | <0.001* | 0.015 (0.012 – 0.019) | 0.812 | 0.005 (-0.034 – 0.044) |
| Contralateral lung V20 | 0.032* | 0.012 (0.001 – 0.023) | 0.877 | 0.002 (-0.019 – 0.023) |
| Contralateral lung MLD | 0.001* | 0.026 (0.011 – 0.041) | 0.512 | 0.013 (-0.027 – 0.053) |
| Both lungs V5 | <0.001* | 0.016 (0.012 – 0.020) | 0.326 | 0.028 (-0.029 – 0.084) |
| Both lungs V20 | <0.001* | 0.026 (0.015 – 0.037) | 0.076 | 0.025 (-0.053 – 0.003) |
| Both lungs MLD | <0.001* | 0.038 (0.022 – 0.053) | 0.538 | 0.013 (-0.056 – 0.029) |
| PTV volume | <0.001* | 0.001 (0.0 – 0.001) | 0.594 | 0.0 (0.0 – 0.0) |
| Dose | 0.494 | 0.011 (-0.044 – 0.021) | | |
| Monitor units | 0.302 | 0.0 (0.0 – 0.0) | | |
| Delivery time | 0.171 | -0.012 (-0.028 – 0.005) | | |
| Arc type | 0.643 | -0.031 (-0.164 – 0.102) | | |
| Technique | 0.786 | 0.033 (-0.211 – 0.278) | | |

Data are presented as regression coefficient (B) and 95% confidence interval (C.I), FEV: forced expiratory volume, MLD: mean lung dose, PTV: planning target volume

Table 9: Correlation between esophagitis and clinicopathological characteristics

| | Esophagitis Grade | | |
|---|---|---|---|
| Characteristic | ≤1, (N = 43) | ≥2, (N = 17) | p-value |
| Arm, No. (%) | | | 0.390 |
| *IMRT* | 23.0 (53.5%) | 7.0 (41.2%) | |
| *VMAT* | 20.0 (46.5%) | 10.0 (58.8%) | |
| Age groups, No. (%) | | | 0.761 |
| *≤ 60* | 17.0 (39.5%) | 6.0 (35.3%) | |
| *> 60* | 26.0 (60.5%) | 11.0 (64.7%) | |
| Sex, No. (%) | | | 0.101 |
| *Female* | 4.0 (9.3%) | 5.0 (29.4%) | |
| *Male* | 39.0 (90.7%) | 12.0 (70.6%) | |
| Smoking, No. (%) | | | 0.346 |
| *Non-smoker* | 12.0 (27.9%) | 8.0 (47.1%) | |
| *Ex-smoker* | 14.0 (32.6%) | 3.0 (17.6%) | |
| *Smoker* | 17.0 (39.5%) | 6.0 (35.3%) | |
| DM, No. (%) | | | 1.000 |
| *No* | 36.0 (83.7%) | 15.0 (88.2%) | |
| *Yes* | 7.0 (16.3%) | 2.0 (11.8%) | |
| HTN, No. (%) | | | 0.661 |
| *No* | 37.0 (86.0%) | 16.0 (94.1%) | |
| *Yes* | 6.0 (14.0%) | 1.0 (5.9%) | |
| Stage, No. (%) | | | 0.055 |
| *IIIA* | 17.0 (39.5%) | 1.0 (5.9%) | |
| *IIIB* | 22.0 (51.2%) | 14.0 (82.4%) | |
| *IIIC* | 4.0 (9.3%) | 2.0 (11.8%) | |
| Side, No. (%) | | | 0.483 |
| *Right* | 27.0 (62.8%) | 9.0 (52.9%) | |
| *Left* | 16.0 (37.2%) | 8.0 (47.1%) | |
| PS, No. (%) | | | 0.811 |
| *0* | 19.0 (44.2%) | 7.0 (41.2%) | |
| *1* | 22.0 (51.2%) | 9.0 (52.9%) | |
| *2* | 2.0 (4.7%) | 1.0 (5.9%) | |
| Esophagus V55, No. (%) | | | |
| *≤10* | 25.0 (58.1%) | 5.0 (29.4%) | 0.045 |
| *>10* | 18.0 (41.9%) | 12.0 (70.6%) | |
| Esophagus mean, No. (%) | | | |
| *≤27* | 25.0 (58.1%) | 6.0 (35.3%) | 0.011 |
| *>27* | 18.0 (41.9%) | 11.0 (64.7%) | |

Data are presented as frequency (%), IMRT: intensity modulated radiotherapy, VMAT: volumetric modulated radiotherapy, DM: diabetes mellitus, HTN: hypertension, PS: performance status

Table 10: Univariate and Multivariate analysis for prediction of ≥ grade 2 esophagitis

| | Univariate | | Multivariate | |
|---|---|---|---|---|
| | p | B (95%C. I) | p | B (95%C. I) |
| Smoking | 0.134 | 0.113 (-0.261 – 0.036) | | |
| Site | 0.445 | 0.091 (-0.146 – 0.328) | | |
| Esophagus V55 | 0.032 | 0.011 (0.001 – 0.021) | 0.318 | 0.005 (-0.005 – 0.016) |
| Esophagus mean | 0.001 | 0.025 (0.010 – 0.039) | 0.010 | 0.021 (0.005 – 0.037) |
| PTV volume | 0.102 | 0.0 (0.0 – 0.0) | | |
| Dose | 0.115 | 0.025 (-0.056 – 0.006) | | |
| Motor units | 0.834 | 0.0 (0.0 – 0.0) | | |
| Delivery time | 0.775 | -0.002 (-0.019 – 0.014) | | |
| N stage | 0.096 | 0.123 (-0.022 – 0.268) | | |
| Arc type | 0.364 | 0.058 (-0.069 – 0.186) | | |
| Technique | 0.399 | 0.100 (-0.135 – 0.335) | | |

Data are presented as regression coefficient (B) and 95% confidence interval (C.I), PTV: planning target volume

## Discussion:

Modern RT methods with advancements in diagnostic and staging tools have been the primary drivers of the recent treatment success rates for locally advanced NSCLC. The therapeutic ratio has been significantly enhanced due to advance in definitive RT. Volumetric modulated arc therapy notably decreases the treatment delivery time compared with IMRT because it allows beam-on when the gantry position, multi-leaf collimator (MLC) moves. Published clinical data on outcome and toxicity using VMAT in lung cancer outside clinical trial are still scarce [7]. A number of studies, including one by Li et al.,2018, have shown that, when compared to IMRT in radiotherapy planning, VMAT approaches have the ability to shorten treatment times without sacrificing plan quality for various diseases [8]. According to Zhang (2019) study it compared conformal radiation therapy, IMRT, ARC, treatment techniques [9]. So, this study is focused on comparison of clinical outcomes and dosimetric parameters between IMRT and VMAT with correlation with clinicopathological characteristics.

The present study enrolled 60 patients with stage III NSCLC treated with CRT including 30 patients treated with IMRT (Group A) and 30 patients treated with VMAT (Group B) concurrent with paclitaxel and carboplatin chemotherapy.

In the current study, no significant differences in patients' characteristics were found between groups of IMRT and VMAT. Most patients in both arms were males, mean age was 62, 63 years in group A, B respectively. Most patients were of performance score 1 in both groups. About 76% of patients in group A were smokers or ex-smokers vs 56% in group B. The most common pathology in both groups was adenocarcinoma, grade 2 and EGFR mutant. Most patients were presented with stage IIIb, T4, N2 disease in both groups. Most patients had mild obstruction by z score of FEV1 in both groups compared to Wijsman et al.,2017 in which 188 patients that underwent (chemo-)radiotherapy with IMRT or VMAT between March 2008 and December 2014, median age was 63, 64 in both groups respectively. Most patients were males, PS >90%, had stage IIIa in both groups, had T2 in IMRT group, T3 in VMAT, N2 in both groups, median FEV1 was 81%, 76% in both groups, CCRT was given to 55%, 74 % in group A, B respectively. Ninety seven percent of A received 66 Gy vs 95% in B [10]. Group A included mainly left sided tumors representing 56.75% of group A. While group B included mainly right sided tumors of about 76.8% of group B. Most patients in group A had central tumors (60%) versus peripheral tumors in group B (70%) compared to Li et al.2018 who included central tumors in 50% of patients and 50% peripheral tumors [8].

In the present study, Median PTV volume in group A was 401.9 cm3 while in group B median PTV volume was 778.4 cm3 with p value = 0.051) compared to Li et al.2018 who enrolled 12 patients with stage II to IIIb lung cancer, received radical radiotherapy, comparing IMRT and VMAT plans demonstrated that PTV volume ranged from 48.78 203.97 cm3 with median PTV volume was 95.1 cm3. In our study, median CI in IMRT group (A) was 0.66 vs 0.64 in VMAT group while heterogeneity index was 0.099 vs 0.15 in group A, B respectively.

As regards ipsilateral lung, V5 and V20 were higher in VMAT while MLD was higher in IMRT with no statistical significance. While Zhao et al.,2015 demonstrated that ipsilateral lung V5 was significantly higher in VMAT, V20 was similar between both groups, MLD was higher in VMAT with statistical significance [11]. Contralateral lung median V5, 20 and MLD were higher in group A with p value (0.723, 0.657 and 0.014 respectively) in comparison with Li et al.,2018 from August 2011 to August 2017, 12 patients were enrolled in the study. The results showed that IMRT had higher V5 of total lungs and contralateral lungs compared to SA, PA, and 2PA VMAT plans for peripheral lung cancer. This is because, in most cases, the tumors were located in lower lobes, so the radiation fields were concentrated and focused on the contralateral lung. When comparing the IMRT plan to SA, PA, and 2PA VMAT plans for PTV including the mediastinum in central lung cancer, the V5 of the contralateral lungs was greater in the former two, while the V20 of the contralateral lungs was lower in the first three [8].

In our study, according to both lungs' parameters, median V5 was almost equal in both groups while median V20 was higher in group B and median MLD was higher group A with non-significant p value compared to the study of Wijsman et al.,2017 who showed that both lungs V5 was higher in IMRT, p=0.02, V20 and MLD were similar between both groups, p=0.33, p=0.99 respectively) [10].

Heart received lower doses in VMAT, but that difference was not statistically significant similar to Choi;2018 where HV10Gy and HV50Gy showed no statistically significant difference, but HV40Gy were statistically significantly lower (7.3% vs. 11.5%; p=0.004) in VMAT plans than IMRT plans. Mean heart dose of VMAT plans was significantly lower than IMRT plans [12].

Median V55 of esophagus was higher in VMAT with significant p value (<0.001). Mean dose reaching esophagus was higher in VMAT which was statistically significant. Median Dmax of spinal cord was lower in VMAT which was not statistically significant similar to Wijsman et al.,2017 in which esophagus V50 and mean dose were higher in VMAT (p=0.04, p=0.22 respectively) and Cash, 2021 who compared IMRT, VMAT and a hybrid combination of IMRT and VMAT treatment planning techniques for right lung cases and showed that spinal cord max dose in IMRT was higher with no significance [9, 10].

In the current study, delivery time was significantly shorter in VMAT with p value <0.001. Monitor units were higher in IMRT with significant p value (p <0.001) consistent with Zhao et al.,2015 who illustrated that delivery time of IMRT plans was (280 s) and that of VMAT plans (114 s); $p < 0.05$). The MUs of IMRT (997) and VMAT plans (509) [11].

In the present study, IMRT had higher overall response (43.3% in group A vs 36.7% in VMAT). Complete response (CR) was achieved in about 3% of patients in each of the two groups. Univariate analysis showed statistically significant relation with smoking, stage, Dmax, Dmean and total dose, while in multivariate analysis, it was significant with smoking and stage.

Appel et al.,2019 in retrospective review of locally advanced NSCLC 74 patients treated from August 2012 to August 2018 with CRT either by 3DCRT, IMRT or VMAT followed by surgery showed favorable pathological response was similar between radiation techniques: for 3DCRT (62.7%) and for IMRT (65.2%) (p = 0.83). The rate of pCR was also similar for 3DCRT (33.3%) and IMRT (34.8%) (p = 0.9). Higher response could be the result of triplet modality approach and IGRT utilization [13].

In our study, in IMRT, median PFS was 10 months while in VMAT, median PFS was 15 months and there was statistically significant difference between the two groups (p = 0.008) similar to Wijsman et al., 2017 who illustrated that median PFS was 11.5 months and 15.1 months in IMRT and VMAT respectively; p = 0.18 but it was not statistically significant [10].

In the present study, grade ≥ 2 pneumonitis was higher in VMAT (33%) vs 30% in IMRT, but it was not significant. Statistically significant differences in APT for IMRT and VMAT could not be observed in Wijsman et al.,2017 study but grade≥ 3 LPT nearly doubled in VMAT group compared to the IMRT and could not be explained by differences in variables associated with lung toxicity (PTV volume, MLD, V20 and V5). Increased LPT after VMAT may be due to patient selection or increased PTV volume [10]. In our study, there was statistically significant correlation between grade ≥2 pneumonitis and lungs' parameters and PTV volume which were all not significant in multivariate analysis similar to Bourbonne et al., 2021 who retrospectively studied patients treated with CRT using VMAT and on univariate analysis, PTV volume and V30 to the ipsilateral lung were significantly associated with increased G ≥2 APT. Only the V30 to the homolateral lung remained statistically correlated with G ≥2 APT on multivariate analysis [14].

Grade 2 or more esophagitis was higher in VMAT with no significant difference compared to Wijsman et al.,2017, Grade 1 AET was reported by 32.3% following VMAT compared to 57.6%, Grade 2 and Grade 3 AET were also more common. In the current study, in univariate analysis of grade ≥2 esophagitis, it was significantly higher in higher esophageal V55, mean esophageal dose, while in multivariate analysis, it was only related to esophageal mean dose with significant P value. Bourbonne et al., 2021 found that AET G ≥2 was observed in 32.4% of patients. On univariate analysis, only age, mean dose, V30 and V60 to the esophagus were significantly associated with a risk of AET >G2. While only age showed significance in multivariate analysis. No clinical or dosimetric features achieved a significant correlation as regard LET [14].

## Conclusion:

Our present study demonstrated that both IMRT and VMAT have almost similar dosimetric parameters

without effect on toxicity. The main significant difference was shorter delivery time and less monitor units in VMAT arm with less cost of treatment. There was no significant difference in response between both techniques. Progression free survival was significantly higher in VMAT compared to IMRT.

**Competing interests**

The authors declare no conflict of interest.

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