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Lung cancer radiation therapy: comparative study between the 3DCRT and IMRT

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Abstract. Background: An effective treatment for lung cancer is radiation therapy. This research set out to compare two radiation treatment strategies for lung cancer, one utilising volumetric modulated arc therapy (VMAT) and the other using intensity modulated radiation therapy (IMRT), to reduce exposure to the liver and contralateral lung**.** Patients and methods: A clinical research study at the Baghdad Center for Radiotherapy and Nuclear Medicine in Iraq involved 30 patients diagnosed with unilateral lung cancer. The study used MONACO software to replicate C.T. scans, develop protocols for IMRT and VMAT, and expose patients to x-ray photon beams. Statistical significance was determined when the p-value was less than 0.05**.** Results: The VMAT treatment planning approach has been demonstrated to be superior to the IMRT technique regarding the minimum, maximum, and mean dosage to the target, as well as the hot and cold regions. Finally, the dose delivered to the liver and lung on the contralateral side should be decreased**.** Conclusion: In Comparison to IMRT, VMAT consistently exhibits superior outcomes in its capacity to target lung tumours while concurrently preserving healthy tissue on the contralateral side.

Keywords: lung cancer, IMRT, VMAT, MONACO, liver.

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Introduction

The respiratory epithelium is the genesis site for the two most common forms of lung cancer. Small cell lung cancers (SCLCs) account for 15% of all lung cancers. These tumours are very aggressive and originate from cells that have neuroendocrine characteristics (1). For the remaining 85% of instances, three main pathologic subgroups of NSCLC—large cell carcinoma, adenocarcinoma, and squamous cell carcinoma—are responsible. Out of all the instances of lung cancer, adenocarcinoma makes up 38.5%, squamous cell carcinoma 20%, and giant cell carcinoma 2.9% (2).

Adenocarcinoma has become more prevalent than squamous cell carcinoma, the previous most common form of non-small cell lung cancer. In the U.S., lung cancer patients had a 15.6% 5-year survival rate between 2001 and 2007, with a 52% survival rate for localised disease and a 3.6% survival rate for distant metastases. Lung cancer was the fourth most common and second leading cause of cancer-related death in females, accounting for 18% of all cancer-related deaths and 13% of all new cancer cases (3,4). In 2008, 1.4 million people were diagnosed with lung cancer, with 1.6 million losing their lives. Radiation treatment for lung cancer is complex and exacerbated by respiratory motion, unequal baseline shifts, and physical changes. Raising the dose to improve treatment outcomes is unlikely due to the large safety margins required. Patients with incurable non-small cell lung cancer often receive stereotactic body radiation therapy (SBRT) in its early stages.

Volumetric modulated arc therapy (VMAT) is a radiation technology that offers highly conformal dose distributions, enhanced target volume coverage, and sparing of normal tissues compared to traditional radiotherapy. It also offers a shorter treatment delivery time than static field intensity-modulated radiation (IMRT) (5–8). VMAT's greatest advantage over traditional multiple-beam IMRT is its quicker delivery time. However, the dosage conformity of VMAT therapy approaches for early-stage and locally progressed lung cancer varies. To reduce toxicity, researchers have been exploring techniques to minimise the risk of narrowly conformal radiation fields missing the tumour in its geographic location (9,10). Four-dimensional computed tomography (CT) has been used to photograph the tumour during at least one complete respiratory cycle and combine images to generate a composite image of the tumour's movement over time. This technique has allowed doctors to confine tumour treatment to a specific part of the respiratory cycle and generate

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radiation target volumes more accurately representing the tumour's real position range during radiotherapy (11–13).

The purpose of this research was to compare two methods of treatment planning for lung cancer, the VMAT plan and IMRT, to find the optimal one that would reduce the risk of side effects in the liver and other organs.

Methodology

A clinical research study with a convenience sampling technique was conducted from September 2023 to July 2024 at the Baghdad Center for Radiotherapy and Nuclear Medicine in Baghdad, Iraq. Ethical consent was taken from each patient. This investigation included 30 patients who were referred to by a radiation oncologist for treatment after being diagnosed with unilateral lung cancer. Before therapy, MONACO version 5.1 software was used to replicate patients' CT scans. The cancer specialist draws a diagram of all possible organs and tumours. A medical physicist develops protocols for IMRT and VMAT. The oncologist selects and approves the best course of action. The Agility linear accelerator from ELEKTA exposed patients to x-ray photon beams of 6 MV or 10 MV. The findings were deemed statistically significant when the p-value was less than 0.05. The data was analysed using SPSS-28, which stands for Statistical Package for the Social Sciences, version 28.

Results

The characteristics of patients included in this study are listed in Table (1). The mean age was 71.62 ± 9.23 years. Most of the patients were female (35%), and the males were 65%, as shown in Figure (1). The body mass index was 29.52 ± 4.52 kg/m2.

Table (1): Characteristics of patients

Characteristics	
Age (Years)	71.62 ± 9.23
Gender	Male: 18 (45%) Female: 22 (55 %)
Body Mass Index (BMI) (Kg/m^2)	26.24 ± 8.11

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The data for the lung dosage was documented and evaluated, as shown in Table (2). The lung tumours in this patient had an average volume of 183.93 ± 52.55 mm3, ranging from 76.7 to 441.6 mm^3. The findings reveal that the IMRT and VMAT are significantly different in terms of maximum and minimum. By "target volume," they imply dosages that achieve that volume. According to the findings in Figure (1), the VMAT administers larger minimum, maximum, and mean doses to the target volume.

Table (2). The Comparison of the Target Volume Coverage Between the IMRT and VMAT.

Parameters	IMRT	VMAT	*p*-value
D_{Min} (cGy)	4188.21 ± 677.23	4974.98 ± 635.07	0.2494
D_{Max} (cGy)	7095.32 ± 549.01	7986.85 ± 350.54	0.0496*
D_{Mean} (cGy)	5077.09 ± 451.05	6145.22 ± 204.55	0.0352*

* Significant Difference at *p*-value ≤ 0.05.

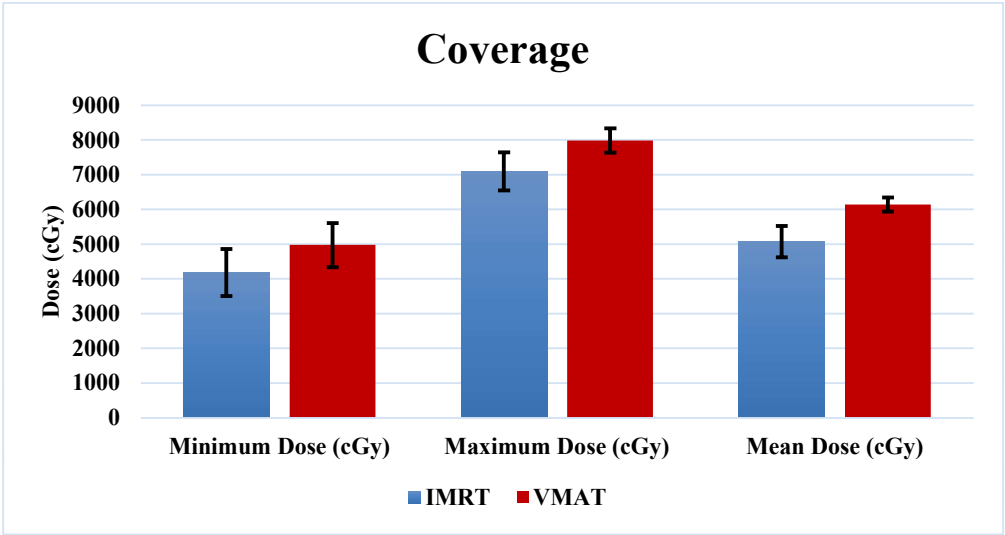

Figure (1). Target Volume Dose Coverage Comparison between IMRT and VMAT, from Minimum to Maximum to Mean.

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As the dosage approached 2% of the volume, the hot region of the dose approached the target volume. Also, cold areas were detected in the Results for both the hot and cold areas, shown in Table (3). Figure (2) indicates that compared to the IMRT, thVMAT's hot region in D2% is much smaller. Compared to VMAT, the cold region in IMRT's isodose 105%, which is significantly higher (3).

Table (3). Hot and Cold Area Coverage Comparison of IMRT and VMAT.

Parameters	IMRT	VMAT	*p*-value
D 2%	6733.05 ± 153.21	6963.99 ± 37.83	0.02179*
D 105%	2.11 ± 0.55	2.88 ± 0.93	0.03352*

* Significant Difference at *p*-value ≤ 0.05.

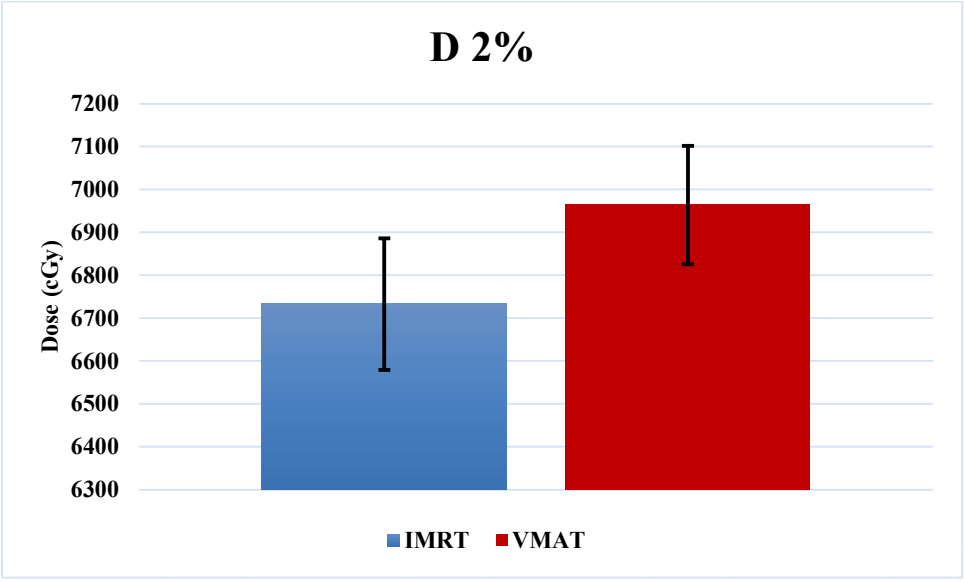

Figure (2). Hot and cold areas at 2% dose coverage coverage for IMRT and VMAT.

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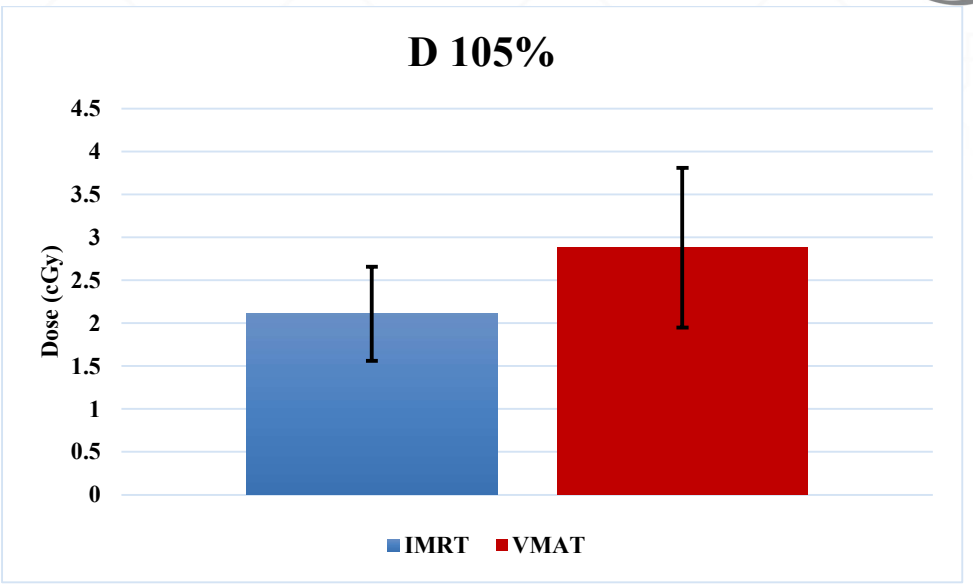

Figure (3). Hot and cold areas account for the dose coverage for IMRT and VMAT.

Table (3) shows the mean doses reached by various organs near the lung. Compared to IMRT, the VMAT treatment planning technique shows a lower overall dose for all organs, as shown in Figure (4). Specifically, compared to IMRT, VMAT delivers a significantly lower mean dose to the contralateral lung. No significant difference was observed at the minimum dose for the liver.

Table (3). The Mean Dose (cGy) of the Organs at Risks for the IMRT and VMAT.

OARs	IMRT	VMAT	*p*-value
Contralateral Lung (cGy)	453.77 ± 49.22	326.75 ± 23.15	0.0172*
Liver(cGy)	105.90 ± 35.02	132.44 ± 20.42	0.0932

* Significant Difference at *p*-value ≤0.05.

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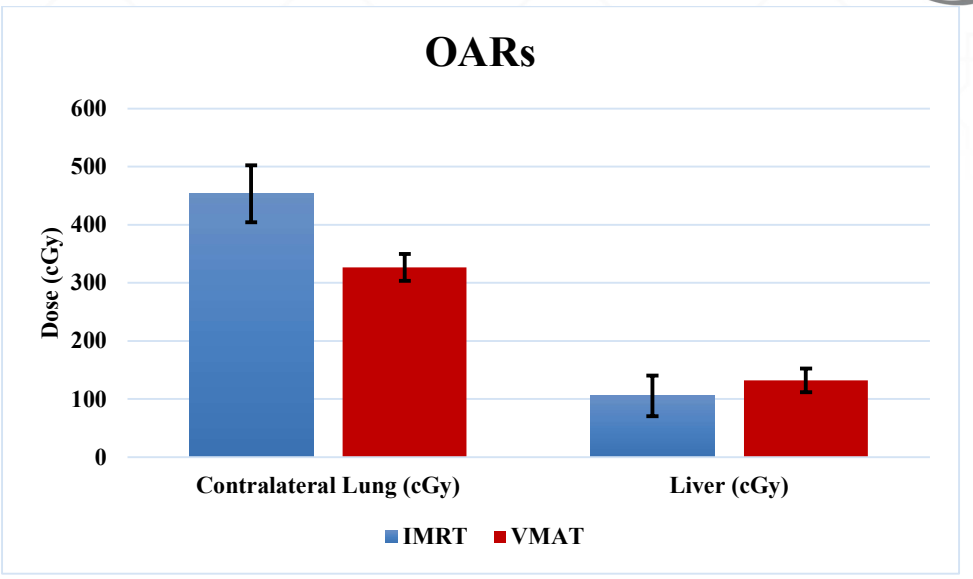

Figure (4). The Dose of Organs at Risk (OARs) for IMRT and VMAT.

Discussion

This research reveals a significant difference between IMRT and VMAT in terms of maximum and minimum. The dosage that produces the target volume is what they're referring to. The results show that compared to IMRT, VMAT offers better coverage. The hot area in D2% is much smaller in the VMAT compared to the IMRT. In contrast to VMAT, IMRT has a much larger cold area between isodose lines 105.

Jiang et al. (9) showed that non-IMRT designs provide superior PTV coverage for locally advanced lung cancer. Lung total and contralateral lobe MLD (mean lung dose) were found to be significantly lowered using VMAT, according to the researchers. According to other research, VMAT regimens are the most effective in helping stage III NSCLC patients achieve their volume and overall activity reduction targets (14,15). The divergent outcomes can be due to one of two things. Multiple instances of the target volume may be associated with a single cause.

Research with 92 patients conducted by Schallenkamp et al. (16) likewise showed a strong association between RIP and V10, V13, and V15. Finding no other biomarker that consistently indicated the presence of RIP (grade 2) in NSCLC patients, they settled on the V5 of both lungs as the only indicator

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(14,15). Although the lung capacity was bigger with VMAT designs, fewer radiation doses were given than IMRT. Consequently, compared to IMRT, VMAT may pose a higher risk of radiation-induced pneumonitis (RIP) in cases of central lung cancer and PTVs without a mediastinum (17). The outcomes of this research are at odds with theirs.

Compared to IMRT, VMAT is the better choice for treating lung cancer, according to many studies. According to Li et al. (18), compared to IMRT plans, VMAT plans provide better PTV coverage for patients with locally advanced lung cancer. Compared to IMRT designs, VMAT plans resulted in significantly lower values for V20, V30, and MLD in the contralateral and total lungs. The results of the additional studies show that the volume and OAR targets for stage III NSCLC were most effectively achieved by VMAT plans (10,11). One possible explanation is that the different target volume scenarios are at play. For example, in one research, the outcomes were different for PTVs that included the mediastinal lymphatic drainage area in central lung cancer compared to PTVs that did not.

Along with the dosimetric analysis, our findings were in line with those of other reported studies (19–21). Both partial and single VMAT arc approaches have been shown to shorten treatment times. VMAT stands to gain from enhancing patient comfort and satisfaction while decreasing intrafraction variance. It has the potential to alleviate pain and poor health, making it easier for patients to make it through a whole treatment session.

Changing the planning system, the accelerator, or the amount of work put into planning may also lead to a better planning approach. The planner's expertise and time spent preparing are two of the most important factors in determining the plan's quality (18,19). The optimisation time for VMAT plans is much higher than that of IMRT, which is one of the major problems with VMAT. The number of possible plan options may rise due to the time and effort constraints imposed by the lengthy optimisation method (22–24). As a result, ensuring the quality of VMAT treatment plans is much more complex than IMRT treatment plans.

There is some variation in the applicability of the planning technique based on tumour stage, size, location, oncotic anchor regions (OARs), and dose-tolerance parameters. However the present study has limitations due to its small sample size, which makes the results less reliable. Further, other IMRT planning processes using additional beams may have been considered; however, implementing such variation might add complexity to the plan but

result in a lengthier treatment duration. Additional clinical research is necessary to resolve these concerns adequately.

Conclusion

Our research shows that when delivering radiation to lung tumours, the VMAT treatment planning method outperforms IMRT while protecting vulnerable organs, including the ipsilateral lung and liver. And since different organs in danger have different requirements, several planning approaches may be necessary. The tumour's stage, size, location, organs at risk, and dose-tolerance characteristics may affect which planning strategy is most appropriate.

Conclusion

In conclusion, the study provides evidence that convulsion and inverse planning methodologies provide unique benefits in the context of Gamma Knife radiosurgery for cavernous malformations. Inverse planning has been shown to provide more protection to vulnerable brain areas and greater conformance. On the other hand, convulsion planning has demonstrated superior selectivity and dosage gradient. The results indicate the possibility of requiring personalised treatment strategies that consider each patient's unique qualities and the parameters of their tumour. The present work provides significant contributions towards the optimisation of Gamma Knife radiosurgery to improve patient outcomes.

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