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RESEARCH ARTICLE OPEN ACCESS

Assessment of Adaptive Radiation Therapy for Non-Small Cell Lung Carcinoma using Intensity Modulated Radiation Therapy

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Abstract
Objective: This study compared clinical and dosimetric outcomes of ART replanning every 5 fractions versus every 10 fractions in patients with non-small cell lung carcinoma (NSCLC).
Methods: This cross-sectional study was conducted at Al Amal National Hospital of Oncology, Baghdad, Iraq, between July 2024 and April 2025. Thirty patients with unilateral NSCLC treated with intensity-modulated radiotherapy were included. Patients were assigned to two groups: Group 1 underwent ART replanning every 5 fractions, while Group 2 underwent replanning every 10 fractions. Demographic variables, gross tumour volume (GTV) changes, dosimetric parameters (planning target volume D95, lung V20, heart V30, and spinal cord Dmax), Gamma Index, and a composite treatment-quality score were evaluated. Statistical analysis was performed using SPSS version 29, with significance set at $p \leq 0.05$.
Results: The groups were comparable in age and weight ($p > 0.05$). Group 1 demonstrated a significantly greater mean GTV reduction than Group 2 (35.26% ± 3.55 vs. 29.20% ± 3.48; $p < 0.0001$). Dosimetric parameters were statistically comparable between groups, although more favourable trends were observed in Group 1. The Gamma Index was higher in Group 1 (97.69% ± 1.33) than in Group 2 (97.02% ± 1.41). The composite quality score was significantly superior in Group 1 (8.69 ± 0.23 vs. 7.87 ± 0.18; $p < 0.0001$). Tumour shrinkage was the primary indication for replanning.
Conclusion: ART replanning every 5 fractions achieves superior tumour volume reduction and overall treatment quality compared with 10-fraction intervals, supporting shorter adaptation schedules for improved therapeutic precision in NSCLC.

Keywords: Intensity Modulated Radiation Therapy (IMRT), Adaptive Radiation Therapy (ART), Dosimetry, Conformity Index, Non-Small Cell Lung Carcinoma (NSCLC)

Plain English Summary

Radiotherapy is a significant intervention for a patient with non-small cell lung cancer (NSCLC). The size and location of the tumour and nearby organs may alter during treatment, thereby decreasing the precision

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of radiation delivery. Adaptive Radiation Therapy (ART) is a current concept which enables changing treatment plans throughout the radiotherapy to consider such changes.
This paper compared two ART plans in 30 patients with NSCLC subject to Intensity Modulated Radiation Therapy (IMRT). The treatment plan in the first strategy was modified after every five treatment sessions, and in the second strategy, it was modified after every ten consecutive sessions. We looked at the effects on tumour size, dose of radiation to the normal organs like lungs and heart and the quality of treatment.
The findings revealed that patients whose treatment plan was reviewed on a five-session basis had a higher decrease in tumour size and overall quality of treatments. The radiation levels received by healthy organs in both groups were comparable, but more frequent updates maintained closer accuracy as the tumour evolved as treatment went on.
These results indicate that a higher rate of radiotherapy plan adjustments to suit the anatomy of the patient would enable the treatment to be more accurate and effective in the treatment of lung cancer patients.

Introduction

Radiotherapy plays a major role in the treatment of Non-Small Cell Lung Cancer (NSCLC), and it poses dosimetric problems, including respiratory movements and changes in anatomy (1, 2, 3, 4, 5, 6, 7, 8, 9). The application of Intensity-Modulated Radiation Therapy (IMRT) and Adaptive Radiation Therapy (ART) has greatly enhanced the accuracy of the delivery of the treatment applied, minimised the local effects of the therapeutic process, and enhanced local control of tumours (10, 11). With IMRT, a specific dosage is administered to irregular tumours, and neighbouring organs are spared. ART enables changes in the treatment plans according to changes in the anatomy or volumetric changes to be modified dynamically. Due to tumour motion, which leads to a decreased dose accuracy, ART provides real-time dose adaptation of the plan to preserve the accuracy of the target and minimise OAR toxicity (12).

The research measures the effect of replanning frequency (5 vs 10 fractions) in ART in the management of NSCLC using IMRT, with the evaluation of dosimetric accuracy and quality of treatment.

Materials and Methods

This is a cross-sectional, clinical study that was conducted between November 2024 and April 2025 at Al Amal National Hospital of Oncology in Baghdad, Iraq. The study was approved by the Institutional Review Board (IRB) of Urmia University of Medical Science, Iran, and provided the necessary ethical clearance to conduct the related study with ID: IR.UMSU.REC.1403.288.

Thirty unilateral NSCLC patients referred for definitive radiotherapy were included. All underwent 3D CT simulation and treatment planning in MONACO v5.1 TPS, delivered on an Elekta Agility LINAC using 6–10 MV photons. Eligible patients had Eastern Cooperative Oncology Group (ECOG) performance status 0–2 and no distant metastases. Patients were positioned supine with both arms raised and immobilised using a thermoplastic mask or vacuum cushion. CT images were acquired and transferred in DICOM format to MONACO v5.1 TPS. GTV, CTV, and PTV were contoured per standard protocol, with a prescription of 60 Gy in 30 fractions (2 Gy/fraction). Table 1 displays the constraints of organs at risk.

Table 1: Normal Range of Organs at Risk (OARs) (13)

Organ at Risk (OAR)	Dose Constraint	Clinical Significance
Contralateral Lung	V20 < 10%	To minimise the risk of radiation pneumonitis
Heart	V30 < 50%, Mean Dose < 26 Gy	Reduces risk of long-term cardiac toxicity
Spinal Cord	Dmax < 45 Gy (standard), < 50 Gy (absolute max)	Prevents radiation-induced myelopathy

Daily image guidance, utilising CBCT and orthogonal kV/MV imaging, confirmed the accuracy of the setup. Re-planning was triggered when target displacement exceeded 5 mm or when dose deviation or volume reduction exceeded 10–15%. Each new plan was re-optimised, QA-verified, and reviewed before implementation

Results

Characteristics of Patients

The mean patient age was 67.8 ± 5.6 years; 56% were male and 44% female, as shown in Table 2 and Figure 1.

Table 2: Overall age and gender distribution of NSCLC patients

Characteristics of Patients	
Age (Years)	67.83 ± 5.61
Gender	Male: 17 (56 %) Female: 13 (44 %)

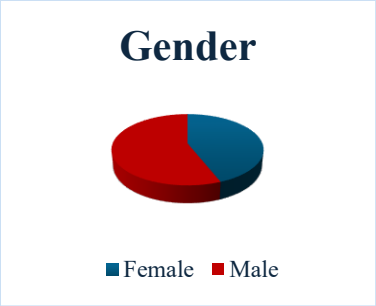


Figure 1: Gender distribution of lung cancer patients

Baseline characteristics were comparable between groups (Table 3). No significant differences were found in baseline or week-3 age and weight ($p > 0.05$)

Table 3: Age and weight distribution according to the groups

Metric	Group 1 (every 5 fractions)	Group 2 (every 10 fractions)	p-value
Age (yrs)	57.93 8.28	60.13 ± 9.26	0.4986
Weight (kg) - Baseline	70.34 ± 8.76	70.38 ±10.1	0.9908
Weight (kg) - Week 3	68.83 ± 8.96	68.87 ± 10.17	0.9895

* An independent t-test is considered significant if the p-value ≤0.05

Dosimetric Outcome

Dosimetric parameters were statistically comparable between 5- and 10-fraction ART groups (Table 4). Lung and heart dose parameters were similar between both groups ($p > 0.05$). Gamma Index was marginally higher in the 5-fraction group (97.7% vs 97.0%), reflecting slightly better delivery accuracy.

Table 4: Dosimetric Metric outcome

Dosimetric Metric	Group 1 (every 5 fractions)	Group 2 (every 10 fractions)	*p*-value
PTV D95 (Gy)	62.12 ± 1.51	62.18 ± 1.62	0.9192
Contralateral Lung V20 (%)	28.19 ± 3.63	28.44 ± 4.47	0.8693
Heart V30 (%)	12.47 ± 4.13	12.07 ± 3.42	0.7709
Spinal Cord Dmax (Gy)	39.38 ± 2.79	39.51 ± 3.03	0.9011
Gamma Index (%)	97.69 ± 1.33	97.02 ± 1.41	0.1926

* An independent t-test is considered significant if the p-value is ≤0.05

Quality of Treatment

GTV %

GTV reduction was significantly greater in the 5-fraction group (35.3% vs 29.2%, $p < 0.0001$) (Table 5). Frequent replanning captured tumour regression more accurately, improving dose conformity and treatment precision.

Table 5: Percentage of Gross Tumour Volume (GTV) Reduction

Group	GTV Reduction (%)
Group 1 (5-fraction ART)	35.26 ±3.55
Group 2 (10-fraction ART)	29.2 ± 3.48
P-value	<0.0001

* An independent t-test is considered significant if the p-value ≤0.05

Composite quality score

The Composite Quality Score was significantly higher for the 5-fraction group (8.69 ± 0.23 vs 7.87 ± 0.18; p < 0.0001), confirming improved overall treatment quality (Table 6, Fig. 2).

Table 6: Composite Quality Score

	Group 1 (5-fraction ART)	Group 2 (10-fraction ART)	p-value
Composite Quality Score	8.69 ± 0.23	7.87 ± 0.18	< 0.0001

* An independent t-test is considered significant if the p-value ≤0.05

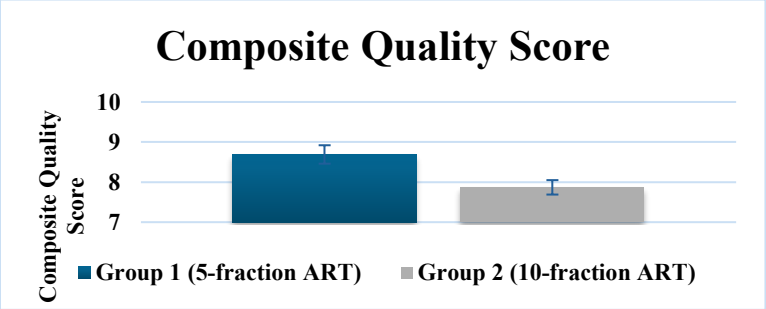


Figure 2: Comparison between Groups 1 and 2 for composite quality score

Reasons for Re-planning

Tumour shrinkage was the main reason for replanning (67% in Group 1, 40% in Group 2), while weight loss and setup errors were less frequent triggers (Table 7). Longer intervals led to more weight-related and geometric changes.

Table 7: Reasons for re-planning NSCLC

Reason	Group 1 (5-fraction ART)	Group 2 (10-fraction ART)
Tumor Shrinkage	10 (67%)	6 (40%)
Weight Loss	3 (20%)	6 (40%)
Setup Error	2 (13%)	3 (20%)
p-value	0.3329	

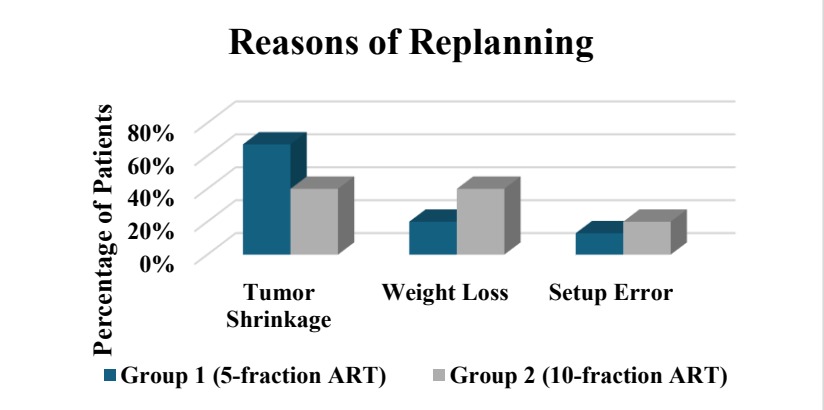


Figure 4: Comparison between the Groups for the reasons for planning

Discussion

Dosimetric Outcome

Both ART strategies produced similar dosimetric outcomes, though the 5-fraction group showed slightly improved precision and plan quality. Frequent adaptation enhances the conformity and reproducibility of setups. Even small reductions in V20 may lower the risk of pneumonitis. More frequent replanning helped compensate for regression and motion, limiting lung and heart doses. This consistency underscores the potential advantage of more regular plan updates in avoiding

cumulative OAR overdosing, particularly as anatomical changes accumulate during a 6–7 week treatment course. Frequent re-planning maintains dose conformity as tumour geometry evolves. The small but statistically significant dosimetric benefits noted in Group 1 of the present study could therefore be attributed to the higher temporal resolution associated with replanning, which allows for better control of dose deposition in real-time.

Our findings align with previous ART studies. Appel et al. (2020) (14) and Guckenberger et al. (2011) (15) also reported 30–40% GTV reduction with weekly adaptation, consistent with our 35% mean reduction. Ohri et al. (2016) (16) confirmed lower lung and oesophagus doses post-midcourse replanning, supporting our dosimetric trends. Zhou et al. (17) and Mitchell (2022) (18) similarly found improved gamma indices with frequent adaptation.

Quality of Treatment

GTV %

This confirms that timely adaptation preserves conformity as tumour geometry changes. Similar studies by Soliman et al. (2013) (19) found that reducing the gross tumour volume (GTV) by almost 38% occurred after 20 fractions; Kandler et al. (2023) (20) concluded that a regression of 30–40 per cent at mid-treatment indicated better survival, and Lee et al. (2024) (21) claimed that a decrease of 30 per cent or more was observed three weeks into treatment. Delayed re-planning may miss optimal response windows and risk geographic misses.

Composite quality score

Higher composite quality in the 5-fraction group supports the value of early adaptation. Most anatomical changes occur within the first two weeks, emphasizing the need for an early adaptive response to maintain coverage and minimise OAR doses. Such an effect is reflected in the work by Noble et al. (2019) (22) In which researchers have observed that the risk of suboptimal dose delivery and poor conformity is real in cases of long intervals between replanning. The same tendency can be noted in the present study; the high-quality scores in measurement of quality were demonstrated in the 5-fraction group, which justified the effectiveness of reduced inter-fraction intervals in enhancing favourable functional performance results.

These conclusions are additionally confirmed by the results of Pogue et al. (2024) (23). Their estimates of plan quality before and after adaptive re-intervention show that early adaptive interventions increase target coverage and sparing of organs at risk. These results are congruent with the better composite scores in the 5-fraction cohort, which proves the overall effectiveness of shorter adaptation periods in high-tech radiotherapy.

Reasons for Re-planning

The most probable reason in the re-planning group was tumour shrinkage, and this re-planning occurred after every 5-treatment cycle, and this was expressed in 67 per cent of re-plans, which was in line with the sensitivity of the non-small-cell lung carcinoma (NSCLC) to radiation therapy. Moreover, frequent reassessments of tumours made it possible to make prompt dosimetric corrections, which kept the target covered without exposing organs to threat. Nevertheless, a re-planning frequency distribution was better balanced in the cohort after radiosurgery that had received 10 fractions. The re-plannings were attributed to two main factors: tumour shrinkage and patient weight loss, each contributing 40% to the total, and setup errors, which accounted for 20% of the re-plannings. The skew toward setup-related causes in Group 2 was likely due to the extended time between assessments, which allowed anatomical and physiological changes to accumulate and impact the replanning decision more frequently. Findings published confirm the same trends: Trommer et al. (2025) (24) indicate that the most popular re-planning stimuli are tumour shrinkage and patient weight loss, accounting for about one-third of all re-plannings. The early identification of tumour regression and reconfiguration through frequent ART, as provided in Group 1, enables timely adjustments to target coverage and shielding of the organ at risk. Less frequent evaluation intervals, such as those used in Group 2, mean that the tumour's mean shrinkage must be greater before replanning. Thus, it is more likely that the effects of weight loss and inherent setup error will become more significant.

Setup errors occurred more frequently in the delayed replanning group. This pattern confirms Terven et al. (2025) (25), who argued that a decrease in ART frequency could lead to an increase in geometric errors as the chances of correction are lost. Overall, studies confirm this fact by showing better response capture of dynamic tumours and reduced systemic and geometric fluctuations using early and frequent adaptive re-planning. Adaptive re-planning of NSCLC is thus reasonable to enhance the precision and effectiveness of treatment.

Conclusion

This study compared the impact of two adaptive radiotherapy (ART) protocols—re-planning after 5 fractions versus 10 fractions—on the quality and dosimetric parameters of treating non-small cell lung carcinoma (NSCLC). A demographic equivalence existed between the two cohorts. Comparison of key dosimetric endpoints, including PTV D95, Lung V20, Heart V30, and Spinal Cord Dmax, revealed no significant differences between the groups, with the 5-fraction cohort exhibiting slightly better mean values. Gross Tumour Volume (GTV) reduction was better in the 5-fraction group (35.26 versus 29.2, $p < 0.0001$), which suggests that with more frequent replanning, it is possible to detect the tumour response promptly. The composite quality score also showed a greater improvement between the five fractions, which showed better overall treatment performance. More frequent replanning achieved superior GTV reduction and plan quality. Such findings suggest that less intense surveillance may delay the detection of clinically significant anatomical variations. Replanning every five fractions enhances treatment precision and adaptation efficiency in NSCLC.

List of Abbreviations

ART: Adaptive Radiation Therapy
CBCT: Cone Beam Computed Tomography
CTV: Clinical Target Volume
D95: Dose received by 95% of the target volume
DICOM: Digital Imaging and Communications in Medicine
ECOG: Eastern Cooperative Oncology Group
GTV: Gross Tumour Volume
IMRT: Intensity Modulated Radiation Therapy
IRB: Institutional Review Board
kV: Kilovoltage
LINAC: Linear Accelerator
MV: Megavoltage
NSCLC: Non-Small Cell Lung Carcinoma
OAR: Organ at Risk
PTV: Planning Target Volume
QA: Quality Assurance
TPS: Treatment Planning System
V20: Percentage of lung volume receiving ≥20 Gy
V30: Percentage of heart volume receiving ≥30 Gy

Declarations

Ethics Approval and Consent to Participate

The Institutional Review Board of Urmia University of Medical Sciences, Iran (Approval ID: IR.UMSU.REC.1403.288) approved this study. Informed consent was taken in writing among all the participants before being included in the study.

Consent for publication

Not applicable.

Availability of Data and Materials

The data sets created and/or processed in the process of the present research are at the disposal of the relevant author on a reasonable request.

Competing interests

The authors indicate that they do not have any competing interests.

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Authors' contributions

FHM and ZA also helped in the supervision and design of the study. ANM assisted in the gathering of data, treatment planning, analysis, and writing of the manuscript. AS helped in clinical coordination and interpretation of data. The final manuscript was read and approved by all the authors.

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