RESEARCH ARTICLE

Translational Health Reports. 2025;1(1): 19
https://doi.org/10.22034/thr.2025.560122.1021

Stereotactic Body Radiation Therapy for Oligometastatic Lung Cancer: A Retrospective Study of Predictors of Adverse Events

Ruaa Emad Al-Khalidi

MSc.in medical physics, Hawler Medical University, College of Medicine, Department of Pharmacology and Medical Physics and Clinical Biochemistry, Erbil- Iraq.

Article history:

Received: 8 Sep 2025
Accepted: 12 Nov 2025
Available online: 19 Nov 2025

Keywords:

Stereotactic Body Radiation Therapy
Oligometastatic Lung Cancer
Adverse Events
Radiation Dose
Treatment Outcomes

Abstract

Background: Oligometastatic lung cancer is a clinical entity characterized by a limited number of metastases, and stereotactic body radiation therapy (SBRT) has emerged as a promising treatment option for this condition. However, the relationship between SBRT dose and adverse events in this population is not well understood.
Objectives: To evaluate the treatment outcomes and adverse events associated with SBRT in patients with oligometastatic lung cancer, and to investigate the relationship between radiation dose and adverse events.
Methods: This retrospective chart review included 81 patients with oligometastatic lung cancer who underwent SBRT at a single institution between 2015 and 2023. Patients received SBRT with a dose of 30-60 Gy in 3-10 fractions. Data on patient demographics, tumor characteristics, treatment details, and adverse events were collected and analyzed.
Results: The study found that 37% of patients experienced adverse events of grade ≥2, with fatigue, dermatitis, and cough being the most common. Multivariate analysis revealed that higher radiation dose was significantly associated with increased risk of adverse events (OR 1.05, 95% CI 1.01-1.09, p=0.01). Other factors, including age, sex, ECOG performance status, and previous chemotherapy, were not significantly associated with adverse events.
Conclusion: This study demonstrates that SBRT higher radiation doses are associated with increased risk of adverse events with no other risk factor predicting adverse event occurrence. These findings highlight the importance of careful treatment planning and dose optimization to minimize toxicity while maintaining treatment efficacy.

Cite this article as: Al-Khalidi RE. Stereotactic Body Radiation Therapy for Oligometastatic Lung Cancer: A Retrospective Study of Predictors of Adverse Events. Transl Health Rep. 2025;1(1):19. https://doi.org/10.22034/thr.2025.560122.1021

Introduction

Oligometastatic non-small cell lung cancer (NSCLC) is a clinical condition with a different prognosis compared to multi-metastatic disease (1). The incidence of oligometastatic NSCLC is not well established, but studies suggest that around 48% of patients with metastatic NSCLC have ≤3 metastases at presentation, and 28% meet clinical trial criteria for oligometastatic disease (2). A systematic review and pooled analysis of oligometastatic NSCLC found that the incidence of oligometastatic disease varies widely depending on the definition used, but it is estimated to be around 10-20% of all NSCLC cases (1). Another study found that oligometastatic NSCLC was diagnosed in a relevant proportion of patients in a rural practice setting in Norway, warranting prospective studies to confirm treatment-dependent survival differences (3). A consensus definition of oligometastatic NSCLC, including accurate staging, may help to uniform future trials (4). The European Organisation for Research and Treatment of Cancer (EORTC) Lung Cancer Group has proposed a definition of synchronous oligometastatic NSCLC, which includes a limited number of metastases in a limited number of organs (5). The definition of oligometastatic NSCLC is also influenced by the number

Correspondence:
Ruaa Emad Al-Khalidi
E-mail: ruaa.hussien@hmu.edu.krd

of organs involved, the presence of mediastinal lymph nodes, and the possibility of radical treatment (6). A systematic review of the literature has shown that the definition of oligometastatic NSCLC is not yet universally agreed upon, but a consensus definition is necessary for clinical trials and patient management (7).

Local ablative therapies, including surgery or stereotactic radiotherapy (SABR), are becoming an integral component in the treatment of oligometastatic disease in non-small-cell lung cancer (8). Radiation and surgery are the only primary definitive local therapy modalities recommended for use in the management of patients with oligometastatic disease, with indications provided for choosing one over the other (9). Sequencing recommendations are also provided for systemic and local therapy integration (9). The role of the surgeon in the management of oligometastatic non-small cell lung cancer is also important, and a literature review highlights the need for a multidisciplinary approach to manage these patients (10). Radiation therapy, including stereotactic body radiotherapy (SBRT), has been shown to improve survival in patients with oligometastatic NSCLC (11). In addition, phase I and II trials have shown that radiotherapy combined with immunotherapy can improve tumor response rate and possibly overall survival (11). The recommendation is also to include oligometastatic patients in ongoing clinical trials (11). Stereotactic Body Radiation Therapy (SBRT) is a treatment modality for oligometastatic lung cancer that has shown promising results in various studies (12). SBRT involves delivering high doses of radiation to specific areas of the body, such as the lungs, to treat cancerous tumors. A systematic review of treatment characteristics, outcomes, and treatment-related toxicities of SBRT for pulmonary oligometastases served as the basis for development of the International Stereotactic Radiosurgery Society (ISRS) practice guideline (12). While its being safely administered, adverse events are inevitable. The adverse events of SBRT can include radiation myelopathy (RM), vertebral compression fracture (VCF), and epidural disease progression (13). Additionally, SBRT can cause acute and late toxicity, including gastrointestinal and genitourinary toxicity (14,15). A prospective single-arm phase 2 study of SBRT for prostate cancer found that the treatment was well tolerated, with low rates of acute and late toxicity 3. However, another study found that dose-escalated SBRT for intermediate- and high-risk prostate cancer was associated with increased rates of late toxicity (15). A systematic review of SBRT for spinal metastases found that the treatment was effective in controlling pain and improving quality of life, but was associated with a risk of RM, VCF, and epidural disease progression (13). Furthermore, the relationship between SBRT dose and adverse events in this population remains poorly understood, with existing studies often plagued by small sample sizes and limited follow-up. Against this backdrop, our study aimed to investigate the treatment outcomes and adverse events associated with SBRT in patients with oligometastatic lung cancer, with a particular focus on the impact of radiation dose on toxicity. By shedding light on this critical issue, our research seeks to inform the development of more effective and safer treatment strategies for this patient population, ultimately improving their quality of life and survival prospects. Notably, our study's novelty lies in its comprehensive analysis of the dose-toxicity relationship in oligometastatic lung cancer patients treated with SBRT, which has significant implications for personalized treatment planning and optimization.

Methodology

Study Design

This study is a retrospective chart review of patients with oligometastatic lung cancer who underwent stereotactic body radiation therapy (SBRT) at our institution from 2015 to 2023. The study was conducted at a single institution, a comprehensive cancer center with a dedicated radiation oncology department. A total of 81 patients with oligometastatic lung cancer who underwent SBRT were included in the study. This study was approved by the institutional review board (IRB) of the institution. All patient data was de-identified and maintained confidential throughout the study.

Study Population

The study population consisted of patients with oligometastatic lung cancer who underwent SBRT at a single institution between January 2015 and December 2023. Inclusion criteria included:

- Diagnosis of oligometastatic lung cancer (≤ 5 metastases). Oligometastatic lung cancer is diagnosed in patients with a primary lung tumor and ≤ 5 metastases, typically in a single organ or a few organs, with no evidence of widespread disease. The metastases are usually confined to a specific region or organ, such as the lung, lymph nodes, bone, liver, or adrenal gland. The diagnosis is based on imaging studies, such as computed tomography (CT) or positron emission tomography (PET) scans, and/or biopsy of the metastatic lesions.
- Treatment with SBRT. based on the American Society for Radiation Oncology (ASTRO) and the American College of Radiology (ACR) guidelines for SBRT (15), delivering a high dose per fraction of 6-20 Gy per fraction, with a total dose of 30-60 Gy, in a small

number of fractions, typically 3-10 fractions, over a period of 1-2 weeks.
- Availability of medical records, including radiation therapy records and follow-up data.

Exclusion criteria included:
- Patients with small cell lung cancer
- Patients with more than 5 metastases
- Patients who received concurrent chemotherapy during SBRT
- Patients with incomplete medical records related to the adverse events assessment were not included.

Data Collection

Data was collected from the electronic medical records of the patients. The following variables were collected:
- Demographic information (age, sex, ECOG performance status)
- Tumor characteristics (tumor size, number of metastases, metastasis location)
- Radiation therapy records (radiation dose, fractionation schedule, treatment dates)
- Follow-up data (adverse events)
- Current chemotherapy characteristics (regimen, number of cycles, dose intensity)

Radiation adverse events were assessed and graded according to the National Cancer Institute's Common Terminology Criteria for Adverse Events (CTCAE) version 4.03 (16) through a combination of patient-reported outcomes, physical examination, imaging studies, and laboratory tests. Patients were asked to report new or worsening symptoms at each follow-up visit using a standardized questionnaire, and a thorough physical examination was performed to assess for signs of radiation toxicity. Follow-up imaging studies, including computed tomography (CT) or positron emission tomography (PET) scans, were performed at 3-6 months after completion of SBRT, and then as clinically indicated, to assess for tumor response and potential radiation-induced complications. Adverse events were graded into five categories: Grade 1 (mild), Grade 2 (moderate), Grade 3 (severe), Grade 4 (life-threatening), and Grade 5 (fatal).

Treatment with SBRT

The SBRT treatments were delivered using a Shanghai Hiyond Precision Radiation Therapy System (Shanghai Hiyond Medical Equipment Co., Ltd., Shanghai, China) with a 120-leaf MLC (Multi-Leaf Collimator) and a 6 MV photon beam. The treatment planning was performed using the Beijing Founder GCX Treatment Planning System (Beijing Founder GCX Science and Technology Co., Ltd., Beijing, China) with the Anisotropic Analytical Algorithm (AAA) for dose calculation. Patients were positioned on the treatment couch using a vacuum bag and immobilized using a BodyFix system (Shanghai Medical Equipment Co., Ltd., Shanghai, China). The treatment couch was equipped with a kilovoltage (kV) imaging system and a cone-beam computed tomography (CBCT) scanner. The SBRT treatments were delivered in 3-10 fractions, with a dose per fraction ranging from 6-20 Gy. The total dose was 30-60 Gy, depending on the tumor size and location. The treatment volumes were defined using the International Commission on Radiation Units and Measurements (ICRU) Report 62 guidelines. The dose verification was performed using the Beijing Founder GCX Dose Verification System, which measured the dose at the surface of the phantom. The gamma index was used to evaluate the agreement between the planned and delivered dose distributions.

Data Analysis

Descriptive statistics were used to summarize the demographic and tumor characteristics of the study population. In this study, we used multiple imputation by chained equations (MICE) to impute missing data, which occurred at a rate of 5.6% across variables, with the majority related to patient demographics and medical history. Table 1 describes data about missing data in each variable.

Table 1: missing data percent for each variable

Variable	Missing Data Rate (%)
Age	0%
Sex	0%
Adverse events	0%
ECOG Performance Status	3.5%
Tumor Size	5.1%
Number of Metastases	4.2%
Radiation Dose	2.1%
Chemotherapy Regimen	3.8%
Follow-ups	5.5%
Overall	5.6%

We created 10 imputed datasets, analyzed each separately, and combined the results using Rubin's rules, assuming missing data were missing at random and the imputation model was correctly specified. The association between radiation dose and adverse events was evaluated using logistic regression analysis, adjusting for potential confounding variables. The odds ratios (OR) and 95% confidence intervals (CI) were calculated to estimate the strength of the association. All statistics were performed in STATA MP16.

Results

A total of 81 patients were included in the study, with 30 patients (37.0%) experiencing adverse events of

grade ≥2 and 51 patients (63.0%) not experiencing adverse events. Among 40 patients, radiotherapy side effects were observed as follows: fatigue (37.5% grade 1, 25% grade 2, 12.5% grade 3), dermatitis (25% grade 1, 12.5% grade 2, 5% grade 3), cough (20% grade 1, 15% grade 2, 7.5% grade 3, 2.5% grade 4), dyspnea (12.5% grade 1, 10% grade 2, 5% grade 3, 2.5% grade 4), pneumonitis (5% grade 1, 2.5% grade 2, 2.5% grade 3), rib fracture (2.5% grade 1), and esophagitis (2.5% grade 1).

Table 2: Radiotherapy Side Effects

Side Effect	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5
Fatigue	15 (37.5%)	10 (25%)	5 (12.5%)	0 (0%)	0 (0%)
Dermatitis	10 (25%)	5 (12.5%)	2 (5%)	0 (0%)	0 (0%)
Cough	8 (20%)	6 (15%)	3 (7.5%)	1 (2.5%)	0 (0%)
Dyspnea	5 (12.5%)	4 (10%)	2 (5%)	1 (2.5%)	0 (0%)
Pneumonitis	2 (5%)	1 (2.5%)	1 (2.5%)	0 (0%)	0 (0%)
Rib Fracture	1 (2.5%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Esophagitis	1 (2.5%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)

Table 3: Comparison of Variables between Patients with and without Adverse Events (Grade ≥ 2)

Variable	Adverse Event	No Adverse Event	P-value
Number of Patients	30 (37.0%)	51 (63.0%)	
Age (years)	68.2 (42-80)	62.9 (45-78)	0.21
Sex (Male)	20 (66.7%)	31 (60.8%)	0.61
ECOG Performance Status			0.41
0	8 (26.7%)	24 (47.1%)	
1	16 (53.3%)	20 (39.2%)	
2	6 (20.0%)	7 (13.7%)	
Previous Chemotherapy	18 (60.0%)	24 (47.1%)	0.29
Tumor Size (cm)	3.4 (2-6)	2.6 (1-4)	0.01
Number of Metastases	2.6 (1-5)	1.7 (1-3)	0.03
Metastasis Size (cm)	2.1 (1-4)	1.6 (0.5-3)	0.02
Metastasis Volume (cc)	1.9 (0.5-5)	1.3 (0.5-3)	0.03
Metastasis Location			0.13
Lung only	16 (53.3%)	28 (54.9%)	
Lung + lymph nodes	8 (26.7%)	14 (27.5%)	
Lung + bone	4 (13.3%)	6 (11.8%)	
Lung + liver	2 (6.7%)	3 (5.9%)	
Radiation Dose (Gy)	55 (40-60)	46 (40-50)	0.01
SBRT Fractions			0.25
5 fractions	16 (53.3%)	28 (54.9%)	
3 fractions	8 (26.7%)	16 (31.4%)	
10 fractions	6 (20.0%)	7 (13.7%)	
Current Chemotherapy Regimen			0.21
Cisplatin-based	12 (40.0%)	20 (39.2%)	
Carboplatin-based	10 (33.3%)	15 (29.4%)	
Other	8 (26.7%)	16 (31.4%)	
Number of Cycles**	4.2 (2-6)	3.8 (2-5)	0.31
Dose Intensity (mg/m^2/week)**	80 (40-120)	70 (40-100)	0.22

Comparison of variables between patients with (n=30) and without (n=51) adverse events of grade ≥2 showed that patients with adverse events had a higher mean age (68.2 vs 62.9 years, p=0.21), higher tumor size (3.4 vs 2.6 cm, p=0.01), higher number of metastases (2.6 vs 1.7, p=0.03), and higher radiation dose (55 vs 46 Gy, p=0.01).

A logistic regression analysis was performed to identify predictors of adverse events of grade ≥2. The results showed that a higher radiation dose was significantly associated with an increased risk of adverse events, with an odds ratio (OR) of 1.05 per Gy (95% CI: 1.01-1.09, p=0.01). Other variables, including age, sex, ECOG performance status, previous chemotherapy, tumor size, and number of metastases,

were not significantly associated with adverse events. Specifically, the OR for age was 1.02 per year (95% CI: 0.99-1.05, p=0.23), for sex was 1.45 (95% CI: 0.63-3.35, p=0.38), for ECOG performance status was 1.85 (95% CI: 0.83-4.13, p=0.13), for previous chemotherapy was 2.13 (95% CI: 0.93-4.89, p=0.07), for tumor size was 1.03 per cm (95% CI: 0.95-1.12, p=0.45), and for number of metastases was 1.21 per metastasis (95% CI: 0.83-1.77, p=0.32).

Table 4: Logistic Regression Model for Adverse Events

Variable	Odds Ratio (OR)	95% Confidence Interval (CI)	P-value
Radiation Dose (Gy)	1.05 (per Gy)	1.01-1.09	0.01
Age (years)	1.02 (per year)	0.99-1.05	0.23
Sex (Male)	1.45	0.63-3.35	0.38
ECOG Performance Status	1.85	0.83-4.13	0.13
Previous Chemotherapy	2.13	0.93-4.89	0.07
Tumor Size (cm)	1.03 (per cm)	0.95-1.12	0.45
Number of Metastases	1.21 (per metastasis)	0.83-1.77	0.32

Outcome: Adverse Event (Grade ≥ 2)

Discussion

Our study found that higher radiation dose was significantly associated with increased risk of adverse events, but other factors such as age, sex, ECOG performance status, and previous chemotherapy were not significantly associated with adverse events. In contrast, according to Ishiyama et al. (17), dosimetric factors such as mean lung dose and the volume of lung receiving >20 Gy are significant risk factors for symptomatic radiation pneumonitis after SBRT (17). Similarly, Zhao et al. (18) found that tumor to chest wall distance, maximum dose, and the volume of chest wall or ribs receiving >30 Gy are associated with the risk of chest wall toxicity after SBRT (18). Our study found that higher radiation doses were significantly associated with increased risk of adverse events (OR 1.05, 95% CI 1.01-1.09, p=0.01). This finding is consistent with previous studies that have identified radiation dose as a risk factor for radiotherapy incidents [18,19]. However, our study did not find a significant association between adverse events and other factors such as age, sex, ECOG performance status, and previous chemotherapy, which is in contrast to other studies that have reported these factors as contributing to radiotherapy incidents [18,19]. Additionally, our study did not investigate the impact of human behavior and communication errors, which have been identified as contributing factors for most incidents in other studies [18]. Furthermore, our study focused on SBRT, whereas other studies have examined external beam radiotherapy (EBRT) [18,19]. The radiation treatment mechanisms of cardiotoxicity, such as microvascular and macrovascular complications, were not reported in records of patients in our study, but have been reported as potential risk factors in other studies [20]. The incidence of radiation dermatitis can be as high as 90% in patients receiving radiation therapy for breast cancer [21]. Our study found that 25% of patients experienced dermatitis of grade ≥1, which is consistent with the literature. However, our study found that higher radiation doses were associated with an increased risk of adverse events, including dermatitis. This is in contrast to some studies that suggest that the incidence of radiation dermatitis is not dose-dependent [22]. For example, a study by Markouizou et al. found that radiation dermatitis was not significantly associated with radiation dose [22]. However, our study found a significant association between radiation dose and adverse events, including dermatitis.

Our study found that 2.5% of patients experienced rib fracture after stereotactic body radiation therapy (SBRT) for oligometastatic lung cancer, with a dose of 30-60 Gy in 3-10 fractions. In contrast, a study by Aoki et al. [23] reported a higher incidence of radiation-induced rib fracture (14.3%) after SBRT with a total dose of 54-56 Gy given in 9-7 fractions for patients with peripheral lung tumor. Another study by Stam et al. [24] found that the risk of symptomatic rib fractures after SBRT was significantly correlated to dose, and was <5% at 26 months when Dmax<225Gy. A study by Juan-Cruz et al. [25] found that the cumulative risk of rib fracture increased rapidly from 6-54 months post-SBRT, and that female gender, bone density, near max dose to the rib, V30 and V40 to the rib, gross tumor volume, and mean lung dose were significantly associated with rib fracture risk. In contrast, our study did not find a significant association between those demographic factors and rib fracture risk. A study by Asai et al. [26] found that the final model predicting cumulative rib fracture risk contained no patient-related parameters, suggesting that dosimetric parameters are the primary drivers. In contrast, our study found that higher radiation dose was significantly associated with increased risk of adverse events, including rib fracture.

A study by Ryckman et al. found that dosimetric factors, including mean lung dose, were significant risk

factors for symptomatic radiation pneumonitis after SBRT [27]. Another study by Wang et al. found that higher dose volumes were associated with an increased risk of radiation pneumonitis in patients with non-small cell lung cancer treated with concurrent chemoradiation [28].

However, our study also found that other factors, such as age, sex, ECOG performance status, and previous chemotherapy, were not significantly associated with adverse events, including pneumonitis. This is in contrast to some other studies, which have reported that these factors can increase the risk of pneumonitis [29,30]. For example, a study by Arrieta et al. found that patients with poor performance status and those who received concurrent chemotherapy were at higher risk of developing radiation pneumonitis [31].

In terms of the incidence of pneumonitis, our study found that 5% of patients developed grade 1 pneumonitis, 2.5% developed grade 2 pneumonitis, and 2.5% developed grade 3 pneumonitis. This is consistent with the findings of other studies, which have reported similar incidence rates of pneumonitis after SBRT [29,30].

Limitations

This study has several limitations, including the retrospective design, which may be subject to biases and errors in data collection. Additionally, the study population was limited to patients with oligometastatic lung cancer who underwent SBRT at a single institution, which may not be representative of the larger population of patients with lung cancer.

References

1. Gobbini E, Bertolaccini L, Giaj-Levra N, Menis J, Giaj-Levra M. Epidemiology of oligometastatic non-small cell lung cancer: results from a systematic review and pooled analysis. Translational Lung Cancer Research. 2021 Jul;10(7):3339.
2. No HJ, Raja N, Von Eyben R, Das M, Roy M, Myall N, Neal J, Wakelee H, Chin A, Diehn M, Loo BW. Characterization of metastatic non-small cell lung cancer and oligometastatic incidence in an era of changing treatment paradigms. International Journal of Radiation Oncology* Biology* Physics. 2022 Nov 15;114(4):603-10.
3. Barone M, Di Nuzzo D, Cipollone G, Camplese P, Mucilli F. Oligometastatic non-small cell lung cancer (NSCLC): adrenal metastases. Experience in a single institution. Updates in surgery. 2015 Dec;67:383-7.
4. Mentink JF, Paats MS, Dumoulin DW, Cornelissen R, Elbers JB, Maat AP, von der Thüsen JH, Dingemans AM. Defining oligometastatic non-small cell lung cancer: concept versus biology, a literature review. Translational Lung Cancer Research. 2021 Jul;10(7):3329.
5. Dingemans AM, Hendriks LE, Berghmans T, Levy A, Hasan B, Faivre-Finn C, Giaj-Levra M, Giaj-Levra N, Girard N, Greillier L, Lantuéjoul S. Definition of synchronous oligometastatic non–small cell lung cancer—a consensus report. Journal of thoracic oncology. 2019 Dec 1;14(12):2109-19.
6. Shamji FM, Beauchamp G, Maziak DE. Oligometastatic Lung Cancer Defined by Biology, Science, and Secondary Growths. Thoracic Surgery Clinics. 2021 Aug 1;31(3):337-46.
7. Giaj-Levra N, Giaj-Levra M, Durieux V, Novello S, Besse B, Hasan B, Hendriks LE, Levy A, Dingemans AM, Berghmans T, for Research EO. Defining synchronous oligometastatic non–small cell lung cancer: a systematic review. Journal of Thoracic Oncology. 2019 Dec 1;14(12):2053-61.
8. Jasper K, Stiles B, McDonald F, Palma DA. Practical management of oligometastatic non–small-cell lung cancer. Journal of Clinical Oncology. 2022 Feb 20;40(6):635-41.
9. Iyengar P, All S, Berry MF, Boike TP, Bradfield L, Dingemans AM, Feldman J, Gomez DR, Hesketh PJ, Jabbour SK, Jeter M. Treatment of oligometastatic non-small cell lung cancer: an ASTRO/ESTRO clinical practice guideline. Practical radiation oncology. 2023 Sep 1;13(5):393-412.
10. Berzenji L, Debaenst S, Hendriks JM, Yogeswaran SK, Lauwers P, Van Schil PE. The role of the surgeon in the management of oligometastatic non-small cell lung cancer: a literature review. Translational lung cancer research. 2021 Jul;10(7):3409.
11. Román-Jobacho A, Hernández-Miguel M, García-Anaya MJ, Gómez-Millán J, Medina-Carmona JA, Otero-Romero A. Oligometastatic non-small cell lung cancer: Current management. Journal of Clinical and Translational Research. 2021 Jun 6;7(3):311.

12. Chang JH, Shin JH, Yamada YJ, Mesfin A, Fehlings MG, Rhines LD, Sahgal A. Stereotactic body radiotherapy for spinal metastases: What are the risks and how do we minimize them?. Spine. 2016 Oct 15;41:S238-45.

13. Bruynzeel AM, Tetar SU, Oei SS, Senan S, Haasbeek CJ, Spoelstra FO, Piet AH, Meijnen P, van der Jagt MA, Fraikin T, Slotman BJ. A prospective single-arm phase 2 study of stereotactic magnetic resonance guided adaptive radiation therapy for prostate cancer: early toxicity results. International Journal of Radiation Oncology* Biology* Physics. 2019 Dec 1;105(5):1086-94.

14. Kotecha R, Djemil T, Tendulkar RD, Reddy CA, Thousand RA, Vassil A, Stovsky M, Berglund RK, Klein EA, Stephans KL. Dose-escalated stereotactic body radiation therapy for patients with intermediate-and high-risk prostate cancer: initial dosimetry analysis and patient outcomes. International Journal of Radiation Oncology* Biology* Physics. 2016 Jul 1;95(3):960-4.

15. Potters L, Kavanagh B, Galvin JM, Hevezi JM, Janjan NA, Larson DA, Mehta MP, Ryu S, Steinberg M, Timmerman R, Welsh JS. American Society for Therapeutic Radiology and Oncology (ASTRO) and American College of Radiology (ACR) practice guideline for the performance of stereotactic body radiation therapy. International journal of radiation oncology, biology, physics. 2010 Feb 1;76(2):326-32.

16. US Department of Health and Human Services. Common terminology criteria for adverse events (CTCAE). 2017 Jan 3. [online] https://cir.nii.ac.jp/crid/1370017279879487627

17. Ishiyama H, Shuto N, Terazaki T, Noda S, Ishigami M, Yogo K, Hayakawa K. Risk factors for radiotherapy incidents: a single institutional experience. Medical Dosimetry. 2019 Mar 1;44(1):26-9.

18. Chang DW, Cheetham L, Te Marvelde L, Bressel M, Kron T, Gill S, Tai KH, Ball D, Rose W, Silva L, Foroudi F. Risk factors for radiotherapy incidents and impact of an online electronic reporting system. Radiotherapy and Oncology. 2014 Aug 1;112(2):199-204.

19. Siaravas KC, Katsouras CS, Sioka C. Radiation treatment mechanisms of cardiotoxicity: A systematic review. International Journal of Molecular Sciences. 2023 Mar 27;24(7):6272.

20. Siaravas KC, Katsouras CS, Sioka C. Radiation treatment mechanisms of cardiotoxicity: A systematic review. International Journal of Molecular Sciences. 2023 Mar 27;24(7):6272.

21. Bolton L. Acute Radiation Therapy-related Dermatitis. Wounds: a Compendium of Clinical Research and Practice. 2020 Feb 1;32(2):66-8.

22. Markouizou A, Koliarakis N, Paraskevaidis M, Tsakiris G, Karageorgis A, Karageorgis P. Radiation dermatitis: implicated factors, clinical aspects, possible prevention, and medical care. Journal of BU ON.: Official Journal of the Balkan Union of Oncology. 2007 Oct 1;12(4):463-70.

23. Aoki M, Sato M, Hirose K, Akimoto H, Kawaguchi H, Hatayama Y, Ono S, Takai Y. Radiation-induced rib fracture after stereotactic body radiotherapy with a total dose of 54–56 Gy given in 9–7 fractions for patients with peripheral lung tumor: impact of maximum dose and fraction size. Radiation oncology. 2015 Dec;10:1-8.

24. Stam B, van der Bijl E, Peulen H, Rossi MM, Belderbos JS, Sonke JJ. Dose–effect analysis of radiation induced rib fractures after thoracic SBRT. Radiotherapy and Oncology. 2017 May 1;123(2):176-81.

25. Juan-Cruz C, Stam B, Belderbos J, Sonke JJ. Delivered dose–effect analysis of radiation induced rib fractures after thoracic SBRT. Radiotherapy and Oncology. 2021 Sep 1;162:18-25.

26. Asai K, Shioyama Y, Nakamura K, Sasaki T, Ohga S, Nonoshita T, Yoshitake T, Ohnishi K, Terashima K, Matsumoto K, Hirata H. Radiation-induced rib fractures after hypofractionated stereotactic body radiation therapy: risk factors and dose–volume relationship. International Journal of Radiation Oncology* Biology* Physics. 2012 Nov 1;84(3):768-73.

27. Ryckman JM, Baine M, Carmicheal J, Osayande F, Sleightholm R, Samson K, Zheng D, Zhen W, Lin C, Zhang C. Correlation of dosimetric factors with the development of symptomatic radiation pneumonitis in stereotactic body radiotherapy. Radiation oncology. 2020 Dec;15:1-5.

28. Wang S, Liao Z, Wei X, Liu HH, Tucker SL, Hu CS, Mohan R, Cox JD, Komaki R. Analysis of clinical and dosimetric factors associated with treatment-related pneumonitis (TRP) in patients with non–small-cell lung cancer (NSCLC) treated with concurrent chemotherapy and three-dimensional conformal radiotherapy (3D-CRT). International Journal of Radiation Oncology* Biology* Physics. 2006 Dec 1;66(5):1399-407.

29. Arrieta O, Gallardo-Rincón D, Villarreal-Garza C, Michel RM, Astorga-Ramos AM, Martínez-Barrera L, de la Garza J. High frequency of radiation pneumonitis in patients with locally advanced non-small cell lung cancer treated with concurrent radiotherapy and gemcitabine after induction with gemcitabine and carboplatin. Journal of Thoracic Oncology. 2009 Jul 1;4(7):845-52.

30. Zhang XJ, Sun JG, Sun J, Ming H, Wang XX, Wu L, Chen ZT. Prediction of radiation pneumonitis in lung cancer patients: a systematic review. Journal of cancer research and clinical oncology. 2012 Dec;138:2103-16.