Original Article

Incidence and Risk Factors of Prolonged Air Leak After Pulmonary Lobectomy: A Prospective Observational Study

Osamah Obaid Ibrahim

ABSTRACT

Objective: To determine the incidence of prolonged air leak after pulmonary lobectomy and identify independent risk factors in an Iraqi tertiary care center.

Study Design: prospective observational study

Place and Duration of Study: This study was conducted at the Nasiriyah Teaching Hospital Iraq from 1st February 2023 to 31st January 2025.

Methods: Prolonged air leak was defined as persistent asthmatic gas leak for ≥7 days postoperatively. Perioperative data were extracted including demographics, comorbidities, surgical approach, intraoperative factors and postoperative outcomes. Independent risk factors for prolonged air leak were identified using multivariable logistic regression analysis.

Results: Overall prolonged air leak incidence in 54 (18.1%) patients. Mean age was 58.7±12.4 years, comprising 62.4% males. Right upper lobectomy was performed most often (34.2%). Independent risk factors for prolonged air leak were: older age (OR 1.04, 95% CI 1.01-1.07, p=0.008), chronic obstructive pulmonary disease (OR 2.89, 95% CI 1.45-5.76, p=0.003), need for adhesiolysis (OR 3.21, 95% CI 1.68-5.76, p<0.001), incomplete fissure (OR 2.45, 95 prolonged air leak patients had significantly longer hospital stay (12.8 vs 6.2 days, p<0.001) and readmission rates (22.2% vs 4.9%, p<0.001).

Conclusion: Prolonged air leak incidence after lobectomy in our Iraqi population aligns with international rates. Identified risk factors enable enhanced preoperative counselling and targeted preventive strategies, potentially improving patient outcomes and reducing healthcare burden in resource-limited settings.

Key Words: Prolonged air leak, Lobectomy, Thoracic surgery, Complications

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INTRODUCTION

Pulmonary lobectomy is the gold standard of care for early stage non-small cell lung cancer and many benign pulmonary conditions with more than 50,000 operations performed each year worldwide.[1] Despite remarkable improvement in surgical techniques and perioperative care, postoperative complications remain to affect patient outcome, with prolonged air leak (PAL) being one of the most common and clinically important.[2,3]

Pulmonary air leak, which classically is defined as a respiratory leak that persists beyond postoperative day 7, is reported to occur in 8-25% of patients after pulmonary resection, with high heterogeneity between populations and health care systems.[4,5]

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This complication greatly lengthens hospital stay, increases health care costs and morbidity, with economic burden in excess of $10,000 per case in developed health care systems.[6]

The pathophysiology of PAL is thought to be due to disruption of visceral pleural integrity with incomplete lung expansion or the failure of air leak sites to seal well.[7] PAL development has been associated with multiple patient-specific variables such as advanced age, chronic obstructive pulmonary disease (COPD), smoking history, and surgical factors including extent of resection, surgical approach and intraoperative complications.[8,9] However, the relative importance of these factors differs substantially across populations and settings of care.

However, little information is available about the incidence and risk factors for PAL in Middle Eastern populations, especially in Iraq's health care setting, despite the clinical importance of PAL. In addition, the unique demographic profile of the study population, the environmental factors and the healthcare infrastructure in Iraq may result in different PAL incidence and risk factors than in western populations.[10] An understanding of these factors is key to improving surgical outcomes,

and to optimizing the allocation of resources in developing healthcare systems.

The purpose of this study is to estimate the prevalence of PAL after pulmonary lobectomy and to identify independent risk factors in an Iraqi tertiary care center.

METHODS

This prospective observational study was performed at Nasiriyah Teaching Hospital, a tertiary referral center that's affiliated with the University of Thi-Qar, Iraq between January 2023 and January 2025 vide letter No. 9352/QM/Approval/KJD863 dated 5-1-2023. All consecutive patients aged >=18 years undergoing elective pulmonary lobectomy for malignant or benign indications were included. The patients of emergency surgery, concurrent chest wall resection, prior ipsilateral thoracic surgery, patients requiring mechanical ventilation >48 hours postoperatively, incomplete follow-up data, and withdrawal of consent by patient were excluded.

All lobectomies were performed by experienced thoracic surgeons using standardised techniques. Surgical approach: VATS or open thoracotomy depending on tumor properties, patient anatomy and surgeon preference. Mediastinal lymph node sampling or dissection was performed systematically in cases of malignancy according to oncological principles. Intraoperative air leak test was done by saline immersion technique at positive pressure of 25-30 cmH2O. Fissure completion was scored and reported. Pleural space drainage was performed by means of 28-32 Fr chest tubes connected to digital drainage devices (Medela Thopaz+, Switzerland) with constant suction level at -20 cmH2O. Comprehensive perioperative data were prospectively collected using standardized case report forms. Variables included:

Patient demographics and comorbidities: Age, gender, body mass index (BMI), smoking history, chronic obstructive pulmonary disease (COPD), diabetes mellitus, cardiovascular disease, previous chemotherapy or radiotherapy, and preoperative pulmonary function tests.

Surgical variables: Indication for surgery, surgical approach (VATS vs. open), lobe resected, operative time, intraoperative complications, blood loss, fissure completeness, requirement for adhesiolysis, and intraoperative air leak presence.

Postoperative variables: Chest tube duration, air leak pattern, complications, hospital length of stay, readmissions within 30 days, and mortality.

PAL definition: Leakage of air persisting ≥7 days after surgery, which is established through the measurements of the digital drainage system and clinical evaluation. Air leak was measured on standard scales and recorded on a daily basis.

The data was entered and analyzed through SPSS-25. The distribution of normality was determined by Shapiro-Wilk test. Student t -test or Mann-Whitney U test were used to analyze continuous variables and chi-square or Fisher exact test was used to analyze non-parametric variables in univariate analysis and variables associated with $p<0.20$ were entered into multivariate logistic regression model to determine independent PAL risk factors. The performance of the models was evaluated in terms of area under the receiver operating characteristic curve (AUC-ROC), Hosmer- Lemeshow goodness-of-fit test and calibration plots.

RESULTS

Sixty-two percent of the participants were male, and the average age varied between 58.7 and 12.4 years. The benign conditions, which include bronchiectasis and inflammatory illnesses, accounted for 21.5% of the indications for lobectomy, while non-small cell lung cancer accounted for 78.5% of the indications (Table 1). The right upper lobectomy, which was conducted the most frequently (34.2% of all surgeries), the left upper lobectomy was performed the second most frequently (28.9% of all treatments). A total of seventy-eight percent of the cases involved the utilization of the VATS method, with eight percent of the VATS operations resulting in the conversion to open thoracotomy (Table 2).

Table No. 1: Baseline patient characteristics and comparison between PAL and non-PAL groups (n=298)

Variable	No PAL (n=244)	PAL (n=54)	p-value
Age (years)	57.8±12.1	62.4±12.9	0.008*
Male gender	149 (61.1%)	37 (68.5%)	0.297
BMI (kg/m²)	25.1±4.1	23.7±4.5	0.032*
Smoking history	154 (63.1%)	44 (81.5%)	0.009*
Pack-years >20	108 (44.3%)	34 (63%)	0.012*
COPD	65 (26.6%)	24 (44.4%)	0.008*
Diabetes mellitus	52 (21.3%)	15 (27.8%)	0.295
Cardiovascular disease	78 (32%)	20 (37%)	0.462
FEV1 (% predicted),	80.1±18.2	71.8±19.8	0.003*
Previous chemotherapy	35 (14.3%)	10 (18.5%)	0.423

Pulmonary embolism was identified to occur at a prevalence of 54 (18.1%) patients affected. The mean air leakage of affected patients was 9.8 above 3.2 days. The table on the left-hand side shows that at the postoperative stage, there exist significant differences in the postoperative outcomes between PAL and non-PAL groups (Table 3, Fig. 1).

A multivariate logistic regression model found five independent risk factors associated with the development of PAL (Table 4). The last model exhibited a sufficient model (AUC-ROC = 0.78, 95% CI 0.72-0.84) and sufficient calibration (Hosmer-Lemeshow p=0.543).

Table No. 2: Surgical characteristics and intraoperative factors

Variable	No PAL (n=244)	PAL (n=54)	p-value
Surgical Approach			
VATS	172 (70.5%)	30 (55.6%)	0.033*
Open thoracotomy	72 (29.5%)	24 (44.4%)	
Lobe Resected			
Right upper	81 (33.2%)	21 (38.9%)	0.187
Right middle	30 (12.3%)	4 (7.4%)	
Right lower	57 (23.4%)	10 (18.55)	
Left upper	69 (28.35)	17 (31.5%)	
Left lower	7 (2.9%)	2 (3.75)	
Operative time (minutes)	179.2±50.8	206.8±57.9	0.001*
Estimated blood loss (mL), median (IQR)	200 (150-300)	300 (200-450)	0.002*
Adhesiolysis required	52 (21.3%)	24 (44.4%)	<0.001*
Incomplete fissure	68 (27.9%)	26 (48.1%)	0.003*
Intraoperative air leak	65 (26.6%)	22 (40.7%)	0.038*
Lymph node dissection	194 (79.5%)	40 (74.1%)	0.377

Table No. 3: Postoperative outcomes and complications

Variable	No PAL (n=244)	PAL (n=54)	p-value
Chest tube duration (days), median (IQR)	4 (3-5)	10 (8-13)	<0.001*
Hospital length of stay (days)	6.2±3.1	12.8±7.9	<0.001*
Postoperative complications			
Pneumonia	15 (6.1%)	8 (14.8%)	0.034*
Atrial fibrillation	12 (4.9%)	6 (11.1%)	0.093
Empyema	2 (0.8%)	3 (5.6%)	0.027*
Respiratory failure	4 (1.6%)	4 (7.4%)	0.032*
30-day outcomes			
Readmission	12 (4.9%)	12 (22.2%)	<0.001*
Mortality	2 (0.8%)	1 (1.9%)	0.477
90-day outcomes			
Mortality	5 (2%)	2 (3.7%)	0.454

Table No. 4: Multivariable logistic regression analysis of independent PAL risk factors

Variable	Odds Ratio	95% Confidence Interval	p-value
Age (per year increase)	1.04	1.01-1.07	0.008*
COPD	2.89	1.45-5.76	0.003*
Smoking history >20 pack-years	2.67	1.34-5.32	0.005*
Adhesiolysis requirement	3.21	1.68-6.13	<0.001*
Incomplete fissure	2.45	1.28-4.68	0.007*

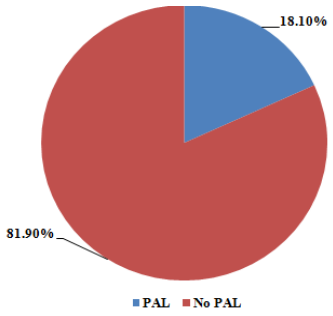

Figure No. 1: Incidence of prolonged air leak (PAL) among patients undergoing pulmonary lobectomy (n = 298)

DISCUSSION

This study showed an 18.1% incidence replying to the international literature ranges of 8-25%.[11] 19.2% PAL incidence in a German multicenter study of 1,247 patients[12], and found 16.8% in a Chinese cohort of 892 patients.[13] The results of our work are important information on the risk factors of PAL in a population in the Middle East, which is underrepresented in the evidence base of developing healthcare systems. This resemblance implies that even though healthcare systems and populations of patients differ, the

underlying biological and surgical conditions that determine PAL are similar regardless of the environment.

Advanced age was an independent risk factor of PAL (OR 1.04 per year, p=0.008), which is similar to numerous other studies.[14,15] The biologic changes in lung compliance, pleural curing ability, and physiological reserve increase with age and lead to a progressive increase in air leaks are similar. Aprile et al[16] demonstrated in a cohort of 1,156 patients, in which age over 65 years related to a considerable higher risk of PAL (OR 1.8, 95% CI 1.2-2.7).

COPD was the most significant patient-related PAL risk factor (OR 2.89, p=0.003), which is consistent with a substantial body of literature supporting the impaired air leakage and elastic recoil in patients with emphysema and the compromised response of the pleural healing process.[17, 18] Our result is also consistent with the analysis of the Society of Thoracic Surgeons database by Heiden et al[19], which found that COPD is an important PAL predictor (OR 2.4, 95% CI 1.8-3.2) on a group of 15,259 lobectomy patients. History of smoking (20 pack-years) was a predictor of PAL (OR 2.67, p=0.005) on its own, as previous smoking history has been shown to predict smoking-associated wound healing impairment and heightened risk of infection.[20] Surprisingly, we had a lower PAL rate among the heavy smokers 24.3% as compared to the reported 31.2%, which could be due to differences in the smoking habit or type of tobacco (common in the Middle East).[21]

Adhesiolysis emerged as the most significant surgical risk factor (OR 3.21, p<0.001) positive indicator of more pleural trauma and abnormality of normal healing processes. The clinical implications include observation who noted 3.1-fold risk of PAL after extensive adhesiolysis[22], and it is important to note that in our population there is larger prevalence of pleural adhesions, which could be due to the endemic respiratory infections and occupational exposures. Incomplete fissure also was a strong predictor of PAL (OR 2.45, p= 0.007), which is rather expected since the literature underlines the significance of fissure anatomy in the formation of air leaks post-surgery.[23,24] Unclosed fissures mean that a lot of dissection and parenchymal division need to be done, leaving several possible sites of air leaks. Preoperative computed tomography fissure assessment is found to be useful in risk stratification and surgery planning[25] as supported by our findings.

Surgical approach (VATS vs. open), unlike some reports, was not significantly predictive of PAL on multivariate analysis, although higher rates of PAL in open operations (25.0% vs. 14.9% p=0.033) appeared on univariate analysis. This implies that the observed relationship between surgical style and PAL could be confounded by factors of case complexity and patient selection as opposed to reflecting a causal relationship.[26] In our cohort, the clinical effect of PAL was large: affected individuals had longer rates of hospitalization (12.8 vs. 6.2 days, p<0.001) and readmission (22.2 vs. 4.9, p<0.001). These findings are consistent with other findings in the world that prove that there is a high healthcare burden in relation to PAL.[27] In resource-constrained health systems such as the case of Iraq, the increased burden of long stays on the already constrained bed capacity and health resources.

The results of the present study have a multifold clinical implication. Risk factors identified make it possible to conduct better preoperative counseling and informed consent procedures, setting realistic expectations about the course of postoperative experience and possible complications. Perioperative management choices such as the choice of chest tube, postoperative care protocols, and discharge planning might be informed by the risk stratification models that include these factors. Moreover, high-risk patients may receive a better preventive plan, such as preoperative pulmonary rehabilitation, smoking cessation programs, or alternative surgery.

CONCLUSION

The number of risk factors including old age, chronic obstructive pulmonary disease (COPD), having a history of heavy smoking, abnormal requirement of adhesiolysis and inadequate fissure anatomy. The evidence-based risk classification and enhance the preoperative counseling, and create more specific preventive measures. The extreme clinical and economic effects of PAL that encompass doubling duration of stay in the hospital and raising the likelihood of readmission underscores the importance of identifying patients at high risk and implementing the right care procedures.

Author's Contribution:

Concept & Design or acquisition of analysis or interpretation of data:	Osamah Obaid Ibrahim
Drafting or Revising Critically:	Osamah Obaid Ibrahim
Final Approval of version:	The above author
Agreement to accountable for all aspects of work:	The above author

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