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Risk Factors of Prolonged Air Leak Following Thoracic Surgery: A Single-Center Observational Study

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ABSTRACT

Background: Prolonged air leak (PAL) is a significant complication following thoracic surgery, leading to increased morbidity and prolonged hospital stays.
Objective: This study aimed to investigate the predictors of prolonged air leak PAL following thoracic surgery.
Patients and Methods: This prospective clinical study enrolled 42 patients who underwent thoracic surgery. They were divided into a PAL group (n=5) and a non-PAL group (n=37). Data collection included patient demographics, surgical details, and postoperative outcomes. PAL was defined as an air leak lasting more than 4 days. Statistical analysis was performed to compare variables between PAL and non-PAL groups.
Results: Obesity (P = 0.002), diabetes mellitus (P = 0.005), chronic obstructive pulmonary disease (P < 0.001), low vital capacity (P < 0.001), low forced vital capacity (P < 0.001), low diffusing lung capacity (P < 0.001), steroid use (P < 0.001), and emphysematous lung (P < 0.001) were significantly associated with PAL. Pleural adhesion (P < 0.001), location of lobectomy (P = 0.026), and operative time (P < 0.001) were also significantly associated with PAL. However, smoking status, cardiovascular disease, previous chest surgery, lobectomy, and number and size of chest tubes, did not significantly correlate with PAL. The duration of hospital stay was significantly prolonged in the PAL group (P < 0.001).
Conclusion: Our study identified several factors associated with PAL following thoracic surgery. These findings contribute to our understanding of PAL risk factors and can guide preventive strategies to improve patient outcomes after thoracic surgery.
Keywords: Prolonged air leak, Thoracic surgery, Pleural adhesion, Risk factors.

INTRODUCTION

Thoracic surgery is a highly specialized medical field focused on treating conditions and diseases that affect the organs within the chest, including the lungs, heart, and esophagus [1,2]. Despite significant advancements in surgical techniques and postoperative care, there are still instances where complications arise, resulting in longer hospital stays and higher morbidity rates. Among these complications, prolonged air leak (PAL) is particularly concerning. PAL refers to air leakage from the lung into the chest cavity, which persists longer than expected. This complication can cause delays in the patient's recovery, increase healthcare expenses, and potentially lead to further complications [3–5].

Several factors have been recognized as predictors of PAL after thoracic surgery. These factors are patient-related, including advanced age, suboptimal pulmonary function, pre-existing lung conditions like chronic obstructive pulmonary disease (COPD) or interstitial lung disease, and obesity. These patient-related factors can adversely affect lung tissue's healing and sealing process, elevating the risk of a persistent air leak [6–8].

Surgical factors also have a significant impact on the development of PAL. The complexity and nature of the surgical procedure, particularly when involving lung tissue resection, can influence the likelihood of air leaks. Implementing techniques such as stapler line reinforcement effectively reduces air leaks by promoting improved tissue approximation and sealing, thereby decreasing the risk of PAL [9,10].

In addition, intraoperative factors, such as high tidal volumes during mechanical ventilation and prolonged surgical duration, have been identified as contributing to an increased risk of PAL [11,12]. The underlying mechanism behind these associations is multifaceted and involves increased tension on suture lines, impaired tissue healing, and reduced lymphatic drainage [13]. By understanding and addressing these intraoperative factors, the risk of PAL can be further minimized.

Preventing PAL is crucial for improving outcomes after thoracic surgery. Strategies to minimize PAL risk include preoperative optimization through thorough assessment, pulmonary function testing, and addressing factors like smoking and underlying lung disease [14,15].

Our study aims to investigate the predictors of PAL following thoracic surgery and to identify effective strategies to prevent its occurrence. By examining patient-related factors, surgical factors, and intraoperative variables, we aim to identify the significant predictors associated with PAL.

PATIENTS AND METHODS

This randomized prospective clinical study was conducted at Al Zahraa University Hospital from May 2023 to August 2023. A total of 42 patients who

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underwent thoracic surgery during the study period were enrolled in the study.

Patient Selection:
All enrolled patients had their data collected, including age, sex, body mass index (BMI), duration of chest tube drainage, type and site of surgery, other pulmonary complications, patient comorbidity, and length of hospital stay. Prolonged air leak (PAL) was defined as an air leak requiring more than 4 days of postoperative chest tube drainage. Patients with a chest tube solely for fluid drainage without air leak were not included in this analysis. Patients were divided into groups I (PAL group) and II (non-PAL group).

Exclusion Criteria:
Certain patients were excluded from the analysis, including those who refused to continue in the study after initial enrollment, cases where video-assisted thoracoscopic surgery (VATS) was the primary treatment, cases of chest wall surgery or diaphragmatic resection surgery, and cases of emergency or chest trauma surgery.

Surgical Procedure:
Operability was determined based on existing guidelines for resections. All thoracic surgeries were performed using selective lung ventilation and a standard thoracotomy approach. Resections were conducted with a manual suture of the bronchus and lung. Two chest tubes were used for all major resections.

Postoperative Management:
Postoperative pain was managed using systemic analgesia. Chest tube management was standardized, with the tube being removed without a pulmonary air leak and when less than 150 ml of fluid was collected from the pleural cavity daily. Patients underwent an active physiotherapy program, including deep-breathing exercises and nasotracheal suction. The chest tube was removed after confirming complete re-expansion of the residual lung.

Ethical Considerations:
The data collection for the registry was reviewed and approved by the institutional review boards of the center. Additionally, approval was obtained from the Research Ethics Committee of the Faculty of Medicine for Girls (Cairo), Al-Azhar University (IRB Number: 887). All study procedures were conducted according to the Declaration of Helsinki (the World Medical Association's code of ethics for studies involving humans). Written informed consent was obtained from all patients before their participation.

Statistical Analysis:
Data on air leak's characteristics among different groups were compared. Continuous variables were presented as means ± standard deviation (SD) and analyzed using independent t-test or Mann-Whitney test. Qualitative data were presented as numbers and percentages and compared between groups using the Fisher's exact test. The confidence interval was set to 95%, and a margin of error of 5% was accepted. Therefore, a p-value of less than 0.05 was considered statistically significant.

RESULTS

Patient characteristics
The difference in age-gender distribution between the PAL and non-PAL groups was not statistically significant **(Table 1).**

Factors associated with prolonged air leak
Obesity, diabetes mellitus, COPD, low vital capacity (VC), low diffusing lung capacity (DLC), and low forced vital capacity (FVC), using steroids, and emphysematous lung showed a significant association with prolonged air leak (PAL). However, smoking status, cardiovascular disease (CVD), chemotherapy and malignancy did not show significant associations with PAL **(Table 1)**.

Table 1: Patient characteristics and factors associated with prolonged air leak

Variables		**PAL** (N = 5)	**Non-PAL** (N = 37)	Total	P-value
Age		52.0±8.57	42.3±14.2	43.4±14.0	0.155*
Sex	**Male**	4 (80%)	21 (56.8%)	25 (59.5%)	0.632
	Female	1 (20%)	16 (43.2%)	17 (40.5%)	
Obesity	**Yes**	5 (100%)	9 (24.3%)	14 (33.3%)	**0.002**
	No	0 (0.0%)	28 (75.7%)	28 (66.7%)	
Smoking	**Yes**	4 (80%)	20 (54.1%)	24 (57.1%)	0.371
	No	1 (20%)	17 (45.9%)	18 (42.9%)	
DM	**Yes**	5 (100%)	11 (29.7%)	16 (38.1%)	0.005
	No	0 (0.0%)	26 (70.3%)	26 (61.9%)	
CVD	**Yes**	1 (20%)	0 (0%)	1 (2.4%)	0.119
	No	4 (80%)	37 (100%)	41 (97.6%)	
COPD	**Yes**	5 (100%)	2 (5.4%)	7 (16.7%)	<**0.001**
	No	0 (0.0%)	31 (83.8%)	31 (73.8%)	
VC	**Low**	5 (100%)	2 (5.4%)	7 (16.7%)	<**0.001**
	Normal	0 (0.0%)	35 (94.6%)	35 (83.3%)	
FVC	**Low**	5 (100%)	2 (5.4%)	7 (16.7%)	<**0.001**
	Normal	0 (0.0%)	35 (94.6%)	35 (83.3%)	
DLC	**Low**	5 (100%)	2 (5.4%)	7 (16.7%)	<**0.001**
	Normal	0 (0.0%)	35 (94.6%)	35 (83.3%)	
Steroid	**Yes**	5 (100%)	3 (8.1%)	8 (19.0%)	<**0.001**
	No	0 (0.0%)	34 (91.9%)	34 (81.0%)	
Emphysematous lung	**Yes**	5 (100%)	3 (8.1%)	8 (19.0%)	<**0.001**
	No	0 (0.0%)	34 (91.9%)	34 (81.0%)	
Chemotherapy	**Yes**	1 (20%)	0 (0.0%)	1 (2.4%)	0.119
	No	4 (80%)	37 (100%)	41 (97.6%)	
Malignancy	**Yes**	1 (20%)	0 (0.0%)	1 (2.4%)	0.119
	No	4 (80%)	37 (100%)	41 (97.6%)	

PAL (Prolonged air leak), DM (Diabetes Mellitus), CVD (cardiovascular disease), COPD (Chronic Obstructive Pulmonary Disease), VC (Vital Capacity), FVC (Forced Vital Capacity), DLC (Diffusing Lung Capacity). *Comparison was made using the Mann-Whitney Test.

Surgical characteristics

Pleural adhesion, location of lobectomy, and operative times showed a significant association with PAL. Previous chest surgery, lesion location, and lobectomy were not associated with PAL (Table 2).

Table 2: Surgical characteristics of the studied patients

		PAL (N = 5)	**Non- PAL** (N = 37)	Total	P-value
Previous Chest Surgery	Yes	1 (20%)	0 (0%)	1 (2.4%)	0.119
	No	4 (80%)	37 (100%)	41 (97.6%)	
Pleural adhesion	Yes	5 (100%)	1 (2.7%)	6 (14.3%)	<0.001
	No	0 (0%)	36 (97.3%)	36 (85.7%)	
Lesion Location	Right	4 (80%)	19 (51.4%)	23 (54.8%)	0.356
	Left	1 (20%)	18 (48.6%)	19 (45.2%)	
Lobectomy	Yes	3 (60%)	12 (32.4%)	15 (35.7%)	0.329
	No	2 (40%)	25 (67.6%)	27 (64.3%)	
Location of lobectomy	Upper lobe	3 (60%)	4 (10.8%)	7 (16.7%)	0.026
	Lower lobe	2 (40%)	33 (89.2%)	35 (83.3%)	
Operative time	Long	5 (100%)	1 (2.7%)	6 (14.3%)	<0.001

	Typical	0 (0%)	36 (97.3%)	36 (85.7%)	

Tube characteristics

The number of tubes used and the size of the tubes did not show a significant difference between the PAL and non-PAL groups. On the other hand, the duration of hospital stay was significantly more prolonged in the PAL group **(Table 3)**.

Table 3. Characteristics of the used tubes for the studied patients and total hospital stay

		PAL (N = 5)	**Non-PAL** (N = 37)	Total	P-value
Tube number	One	2 (40%)	10 (27%)	12 (28.6%)	0.613
	Two	3 (60%)	27 (73%)	30 (71.4%)	
Tube size	>36 Fr	3 (60%)	27 (73%)	30 (71.4%)	0.613
	<36 Fr	2 (40%)	10 (27%)	12 (28.6%)	
Total Hospital stay	Prolonged	5 (100%)	1 (2.7%)	6 (14.3%)	<0.001
	Typical	0 (0%)	36 (97.3%)	36 (85.7%)	

DISCUSSION

The study findings shed light on several factors associated with PAL following chest surgery. Patient characteristics revealed that obesity was significantly linked to PAL, while smoking did not show a significant association. DM was strongly associated with PAL, whereas CVD did not correlate significantly. COPD and impaired lung function were significantly associated with PAL. Using steroids and emphysematous lungs were also significantly associated with PAL, while chemotherapy and malignancy did not show significant associations.

Previous chest surgery and lesion location did not significantly correlate with PAL among surgical characteristics. However, the presence of pleural adhesion was strongly linked to PAL. Lobectomy did not show significant associations, but the location of lobectomy was associated with PAL. Tube characteristics, including the number and size of tubes, did not show significant associations with PAL. However, a longer total hospital stay was significantly associated with PAL, with all PAL patients experiencing a prolonged stay.

Comparing the results of our study with previous studies reveals several similarities and differences. There was no statistically significant association between age and PAL [16–19]. However, the current study identified obesity as a significant risk factor for PAL, whereas **Stolz *et al.*** did not report a significant association with body mass index (BMI) [19]. Regarding surgical characteristics, no significant association was observed between the type of lobectomy and PAL [17,19]. However, the current study revealed a significant association between the location of lobectomy and PAL, particularly noting that lower lobe procedures had a higher risk. Regarding intraoperative predictors, **Stolz *et al.*** highlighted pleural adhesions and incomplete fissures as risk factors for PAL, which aligns with our study's finding of a significant association between pleural adhesion and PAL. They also identified upper lobectomy and longer lung stapling length as risk factors, which were not specifically addressed in our study [19].

Lee *et al.* emphasized the association between previous chest surgery and PAL, supporting the current study's findings regarding pleural adhesion [16].

The meta-analysis by **Zheng *et al.*** supports the current study's findings, indicating associations between steroid use and PAL incidence. They also found no significant difference between left-sided and right-sided lung resection, which aligns with the current study's results [6].

The study's findings on patient characteristics associated with PAL following chest surgery have important clinical implications. While age and gender did not show a statistically significant association with PAL, they should still be considered when managing patients [7,20]. Obesity, DM, and COPD were significantly associated with PAL, highlighting the need for weight management, glycemic control, and comprehensive lung function assessment in these patients [21,22].

Low VC, FVC, and DLC were also significantly associated with PAL, emphasizing the importance of preoperative pulmonary function testing [23].

The location of lobectomy was a determining factor in the risk of PAL, with a higher association observed in lower lobe procedures. PAL was also significantly associated with prolonged operative time and extended hospital stay. To improve patient outcomes, surgeons should focus on implementing efficient surgical techniques and providing thorough postoperative care to reduce the incidence of PAL. It is crucial to prioritize strategies that minimize PAL and optimize recovery for patients undergoing chest surgery.

The study has notable strengths and limitations. Its strengths lie in its prospective design, and comprehensive study of various patient, surgical, and tube characteristics. The statistical analysis was robust and provided dependable associations between the variables studied.

However, there are limitations to be acknowledged. The study was conducted at a single center, which may restrict the generalizability of the surgical team's experience settings. The small sample size may limit the ability to detect smaller associations with sufficient statistical power. Additionally, the analysis did not consider certain confounding factors, such as variations in surgical techniques or the surgical team's expertise.

CONCLUSION

The findings of the current study shed light on various factors that can contribute to PAL after chest surgery. Risk factors such as obesity, diabetes mellitus, COPD, impaired lung function, steroid use, emphysematous lung, and pleural adhesion are significant contributors to PAL. Recognizing and addressing these factors is crucial for preventing and effectively managing PAL, leading to improved outcomes for patients undergoing chest surgery.

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