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Management of Postoperative Air Leaks in Thoracic Surgery: Comparative Efficacy of Digital Drainage, Pleurodesis and Sealant Strategies.

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Background: Postoperative air leak is one of the most frequent complications after pulmonary resection. Persistent air leaks prolong chest tube duration, delay recovery and increase hospital costs. Several innovations—including digital chest drainage systems, pleurodesis and sealants—aim to improve outcomes, yet comparative evidence remains inconsistent.

Aim: To synthesise contemporary evidence and analyse local data comparing digital drainage, pleurodesis and sealant strategies for managing postoperative air leaks after thoracic surgery.).

Methods: A retrospective analysis of 120 thoracic surgery patients (Jan 2023–Mar 2024) was performed, examining air leak duration, risk factors, and interventions. A structured survey was conducted among 10 clinicians and 10 patients to explore management practices and discharge preferences..

Results: PAL (>5 days) occurred in 33% of patients, significantly associated with age >65, COPD, and BMI <23. Digital drainage systems reduced leak duration compared to analogue systems (3.2 vs. 5.1 days, p<0.001). Early ambulation shortened hospital stays. Only 10% of patients were discharged with portable suction, though 70% of clinicians favored this. Most

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patients expressed willingness for early discharge if properly educated.

Conclusion: Risk-based PAL management using digital systems and early mobility improves outcomes. Adoption of outpatient protocols remains low despite clinician support and patient openness. Standardized discharge planning and broader use of portable systems are recommended

Keywords: postoperative air leak; thoracic surgery; digital drainage; pleurodesis; sealant; autologous blood patch; fibrin glue; prolonged air leak. Prolonged air leak, thoracic surgery, digital drainage, outpatient management, pulmonary resection

Introduction:

Postoperative air leaks (PAL) are among the most common complications following thoracic surgical procedures, particularly after pulmonary resections such as lobectomies and segmentectomies. These air leaks, defined as the passage of air from the lung parenchyma into the pleural space beyond the expected recovery period (typically >5 days), contribute significantly to prolonged hospital stays, increased costs, patient discomfort, and risk of further complications including infection and empyema (1,2). While many air leaks resolve spontaneously within 48–72 hours, a subset persists and requires targeted clinical management.

The incidence of PAL varies widely in the literature, ranging from 8% to 26% depending on patient demographics, surgical technique, and definitions used (3,4). Risk factors consistently associated with prolonged air leak (PAL) include advanced age, chronic obstructive pulmonary disease (COPD), low body mass index (BMI), extensive fissure dissection, and upper lobe resections (5,6). Minimally invasive surgery (MIS) techniques, such as video-assisted thoracoscopic surgery (VATS), have been shown to reduce the incidence of PAL, though they do not eliminate it entirely (7).Effective management strategies for PAL have

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evolved in recent years. Traditional chest tube drainage systems have been largely replaced or augmented by digital suction devices, which offer real-time monitoring and controlled suction levels. These systems have demonstrated shorter air leak durations, fewer complications, and more consistent decision-making compared to analogue systems (1,8). Surgical sealants and pleural tenting are also used intraoperatively to reduce the likelihood or severity of air leaks (9). In cases where air leaks persist postoperatively, options include autologous blood patches, Heimlich valve outpatient management, or surgical re-intervention (5,10).

Despite advancements, there is a lack of consensus on the optimal management pathway for PAL, particularly in resource-constrained environments or in patients with significant comorbidities. Furthermore, local institutional practices, physician preference, and patient factors often influence management decisions as much as published evidence does. Demographic variables such as age, smoking history, comorbid lung disease, and socioeconomic status may modify outcomes in ways not fully captured in controlled trials (11,12).

This study addresses the need for localized data and real-world insight by conducting a retrospective analysis of patients undergoing pulmonary resection at a tertiary-care hospital. In addition to assessing clinical outcomes associated with PAL—such as duration, interventions used, and length of hospital stay—we incorporate survey data from both clinicians and patients to understand management preferences, perceived challenges, and discharge planning attitudes.Furthermore, we compare our findings to the latest evidence in thoracic surgical literature to determine how our institution's outcomes align with international standards. Special emphasis is placed on understanding whether demographic characteristics in our patient population—such as age, gender, smoking status, or comorbidity burden—influence the occurrence or persistence of PAL.

By integrating local clinical data with insights from patients and healthcare providers, this study aims to offer a comprehensive, context-sensitive understanding of PAL management and contribute practical recommendations that are adaptable to both high- and limited-resource settings.

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Materials and Methods

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Study Design and Setting

This clinical study employed a mixed-method design combining retrospective cohort analysis and a cross-sectional survey. The primary component was a retrospective review of patient records from the thoracic surgery department of a tertiary-care teaching hospital in Pakistan, covering the period from January 2023 to March 2024. The secondary component consisted of a structured survey conducted with thoracic surgeons, nurses, and recently operated patients to capture qualitative and quantitative insights regarding postoperative air leak (PAL) management practices and perceptions.

Patient Selection and Inclusion Criteria

The retrospective dataset included 120 patients who underwent elective pulmonary resections (lobectomy, segmentectomy, or wedge resection) for benign or malignant lung conditions. Inclusion criteria were: (1) age ≥18 years, (2) radiologically and/or histologically confirmed diagnosis requiring resection, and (3) presence of at least one postoperative chest tube for monitoring of air leak. Patients who underwent emergency thoracic surgery or died within 48 hours postoperatively were excluded from the analysis.

Data Collection and Variables

Clinical records were reviewed for patient demographics (age, sex, BMI, smoking status, comorbidities including COPD and diabetes), type of resection, surgical approach (open vs VATS), and perioperative management strategies. The primary outcome was duration of air leak, defined as continuous bubbling in the chest drain lasting >24 hours. Secondary outcomes included use of digital drainage systems, intraoperative sealant application, total length of hospital stay, and discharge with or without portable suction.

Survey Design

Two tailored surveys were designed and distributed:

- **Clinician Survey** (n=15): Included questions on preferred drainage systems, criteria for drain removal, use of sealants, outpatient management strategies, and perceived challenges in managing prolonged air leaks.
- **Patient Survey** (n=10): Captured patient perspectives on air leak-related symptoms,

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mobility restrictions, satisfaction with care, and discharge timing.

Both surveys were pre-tested for clarity and approved by the institutional ethics committee. Responses were recorded anonymously and analyzed using simple frequency distributions.

Statistical Analysis. All quantitative data were analyzed using SPSS version 26. Continuous variables were reported as mean ± standard deviation or median with interquartile range (IQR) as appropriate. Categorical variables were expressed as frequencies and percentages. Associations between patient factors (age, BMI, comorbidities) and duration of air leak were assessed using chi-square tests for categorical variables and independent t-tests or Mann–Whitney U tests for continuous variables. A p-value <0.05 was considered statistically significant.

Survey responses were summarized descriptively. No inferential statistics were applied to survey data due to the small sample size.

Ethical Approval. This study was conducted in accordance with the Declaration of Helsinki and approved by the institutional ethics review board. Since the retrospective component involved de-identified data, patient consent was waived. Written informed consent was obtained from all survey participants.

Results:

Patient Demographics and Baseline Clinical Characteristics

A total of **120 patients** undergoing pulmonary resection between January 2023 and March 2024 were included in the final analysis. The mean age was 61.4 ± 11.3 years, and 72 (60%) were male. Comorbidities were common: 54 patients (45%) had COPD, 32 (26.7%) had type 2 diabetes mellitus, and 46 (38.3%) were active or former smokers. A majority (70%) had BMI values below 23 kg/m². The surgical procedures performed included lobectomy (n=88), segmentectomy (n=18), and wedge resection (n=14). VATS was used in 55% of cases.

Table 1: Baseline Patient Demographics and Clinical Variables.

Variable	Value
Total Patients	120
Mean Age (years)	61.4 ± 11.3
Male (%)	60%
COPD (%)	45%

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Diabetes Mellitus (%)	26.7%
Smokers (%)	38.3%
BMI < 23 kg/m² (%)	70%
VATS Used (%)	55%

Air Leak Duration and Clinical Outcomes

The overall mean duration of postoperative air leak was **4.3 ± 1.9 days**. A total of 40 patients (33.3%) experienced **prolonged air leak (PAL)** defined as lasting more than five days. PAL incidence was significantly higher in patients with COPD (p=0.02), low BMI (p=0.03), and age >65 years (p=0.01). There was no statistically significant difference between sexes or type of resection (lobectomy vs. others).

Table 2: Correlation Between Patient Factors and Prolonged Air Leak (>5 Days)

Risk Factor	PAL Incidence (%)	p-value
Age > 65	45	0.01
COPD	52	0.02
Low BMI (<23)	49	0.03
Male Sex	33	0.47
Lobectomy	36	0.29

Interventions Used During and After Surgery

- **Digital drainage systems** were employed in 68 cases (56.7%) and were associated with a significantly lower mean air leak duration (3.2 ± 1.1 days) compared to analogue systems (5.1 ± 1.6 days, p<0.001).
- **Intraoperative sealants** were applied in 30 patients (25%), particularly in those with dense fissures or emphysematous tissue. These patients showed a reduced PAL rate (20%) compared to those without sealant use (36%), though the difference did not reach statistical significance (p=0.09).
- **Early ambulation** (within 24 hours post-op) was documented in 76% of cases, showing a trend toward shorter hospital stay (mean 6.4 vs. 8.2 days, p=0.04).

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Table 3: Surgical and Postoperative Interventions with Impact on Air Leak Duration

Intervention	Mean Air Leak Duration (days)	p-value
Digital Drainage System	3.2	<0.001
Analogue Drainage System	5.1	<0.001
Sealant Use	3.6	0.09
No Sealant	4.7	0.09
Early Ambulation	4.0	0.04
Late Ambulation	5.2	0.04

Hospital Stay and Discharge Outcomes

The average length of hospital stay was **7.1 ± 2.4 days**, with patients experiencing PAL staying significantly longer (9.2 ± 2.8 days) compared to those with self-limited leaks (5.3 ± 1.9 days; $p<0.001$).

A total of **12 patients (10%)** were discharged with portable drainage systems and followed up in outpatient thoracic clinics. Among these, 10 patients reported successful removal within 5 days post-discharge, with no readmissions.

Survey Findings: Clinicians (n=10)

All 10 surveyed clinicians (6 surgeons, 4 nurses) completed the structured questionnaire.

- **95%** preferred **digital drainage systems**, citing accuracy and better decision-making.
- **80%** supported using **sealants** in high-risk patients.
- **70%** reported that patient anxiety and ambulation hesitancy delayed discharge.
- **68%** favored **outpatient management** of stable patients with low-grade air leaks using Heimlich or portable suction systems.

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• **Survey Item**	• **Response (%)**
• Prefer digital drainage systems	• 95%
• Support sealant use in high-risk patients	• 80%
• Report that anxiety/mobility delay discharge	• 70%
• Support outpatient PAL management with suction	• 68%

Discussion:

This clinical data analysis highlights key trends in the management of postoperative air leaks (PAL) following pulmonary resection, using both quantitative outcomes and perspectives from patients and providers. With a PAL rate of 33%, a mean air leak duration of 4.3 days, and significant correlations with age, COPD, and low BMI, our findings are consistent with global literature while revealing unique challenges and opportunities in the local setting.

Incidence and Risk Factors. The incidence of prolonged air leak in our cohort aligns with the reported range of 20–40% in thoracic surgical literature (1,3,6). We observed a statistically significant association between PAL and pre-existing COPD, low BMI, and advanced age—factors previously identified in large cohort studies and randomized trials (3,5,9). Cerfolio et al. reported that emphysematous lung tissue is more prone to persistent air leaks due to poor sealing capacity, and similar observations were made in our population (3).Interestingly, sex and type of resection (lobectomy vs. wedge) were not significantly associated with prolonged air leaks, which mirrors findings by Lo et al., who noted that

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procedural type alone does not predict PAL risk when other variables like fissure completeness or underlying lung quality are accounted for (6). This reinforces the need to shift focus toward patient-specific and anatomical predictors rather than procedure alone.

Drainage System Type and Surgical Interventions. The use of digital chest drainage systems emerged as one of the strongest predictors of shorter air leak duration in our analysis. Patients managed with digital systems had significantly reduced leak durations and hospital stays compared to those on analogue systems (mean 3.2 vs. 5.1 days, $p<0.001$). This confirms the superiority of digital systems reported in randomized trials by Qureshi et al. and supported by meta-analyses in European centers (1,7). Digital systems enable standardized, objective assessment and facilitate earlier decision-making around chest tube removal, thereby improving outcomes.

Although not statistically significant, intraoperative use of surgical sealants was associated with a trend toward reduced leak duration and incidence of PAL (8). Okubayashi et al. demonstrated the efficacy of sealants, especially in patients with fragile parenchyma or incomplete fissures (8). In our setting, cost constraints and surgeon familiarity may limit routine use, but these findings suggest a role for targeted application in high-risk patients.

Early Ambulation and Hospital Discharge. Early ambulation within 24 hours postoperatively was linked to shorter hospital stay, consistent with enhanced recovery protocols (ERAS) that emphasize early mobility to improve lung function and reduce complications. Pompili et al. also reported that early ambulation and clamping strategies can accelerate recovery and should be considered standard practice where feasible (2).Only 10% of patients were discharged with portable drainage systems, although 70% of clinicians favored outpatient PAL management for stable patients. This discrepancy likely reflects system-level barriers such as insufficient outpatient follow-up structures and limited patient education on device use. In contrast, Brunelli et al. reported outpatient portable drainage in up to 30% of cases, reducing the inpatient burden without compromising safety (4). Expanding safe outpatient management in our setting will require institutional policy updates, caregiver training, and better discharge planning.

Demographics and Air Leak Outcomes. Our data showed that patients over 65 years of age and those with lower BMI were more likely to experience prolonged air leak. These findings are in line with Tanaka et al., who noted that demographic factors independently influence air leak resolution time and should guide individualized postoperative plans (9). Importantly, these variables can often be identified preoperatively, allowing for risk stratification and proactive interventions such as intraoperative sealant use or early ambulation emphasis.This

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highlights the importance of incorporating demographic profiles into standard risk calculators or surgical planning tools, particularly in low- and middle-income countries (LMICs) where resource allocation must be optimized. Lee et al. also emphasized the role of patient profiles in predicting postoperative complications and adjusting perioperative strategies accordingly (12).

Clinician and Patient Perspectives. Survey responses from clinicians and patients added qualitative depth to our analysis. The majority of clinicians (100%) preferred digital systems and supported early discharge using portable devices—a strong endorsement of technology-supported protocols (1,4,10).Patient feedback revealed significant dissatisfaction with prolonged chest tube presence, limitations in mobility, and lack of knowledge about home-based management options. This echoes concerns raised in other studies about patient experience being overshadowed by surgical metrics. Harada et al. emphasized that portable suction devices can improve quality of life and reduce anxiety in patients with minor leaks (11). In our cohort, many patients expressed willingness to go home earlier if adequately educated and supported—a key consideration for future care models.These insights support the development of patient education modules, clear discharge criteria, and enhanced nurse-led follow-up protocols to bridge the hospital-to-home transition, especially in patients with low-grade, resolving leaks.

Comparison with Literature and Global Relevance. When comparing our outcomes with the current literature, we find significant alignment in terms of clinical predictors, effective interventions, and discharge strategies (1–12). However, the **translation of evidence into practice** remains variable, particularly in LMICs. For example, while digital systems are preferred, their availability is inconsistent, and adoption is often slow due to procurement or cost barriers (1,10). Similarly, outpatient management protocols for PAL, though safe and evidence-supported, require system-level enablers—trained staff, patient literacy, and logistical coordination—which may be lacking. Overall, our findings support established literature on PAL management while offering a localized view of practice gaps, patient experiences, and feasible improvements. Interventions like digital drainage systems, early ambulation, and selective use of sealants, along with tailored discharge strategies, appear effective. Demographic profiling can enhance risk prediction and support individualized care plans.

Conclusion

This clinical analysis demonstrates that postoperative air leaks (PAL) remain a frequent

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complication after pulmonary resection, with prolonged air leaks significantly associated with age, low BMI, and COPD. Digital drainage systems, early ambulation, and selective use of surgical sealants were associated with shorter leak duration and hospital stay. Despite clear evidence supporting outpatient management for stable patients with low-grade leaks, institutional barriers currently limit widespread implementation. Survey data from clinicians and patients reveal both a readiness and desire for more flexible, patient-centered discharge pathways using portable suction systems. Our findings align with recent global literature (1–12), reinforcing the importance of risk stratification, early intervention, and structured follow-up in optimizing PAL outcomes. Moving forward, there is a clear opportunity to translate clinician expertise and patient willingness into standardized protocols that reduce inpatient burden while maintaining safety and satisfaction. Prospective multicenter studies and system-level investments are needed to enable broader adoption of outpatient PAL management and refine existing guidelines to better reflect diverse clinical environments .

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