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Original Article

Operative Strategies and Long-Term Outcomes in Fungal and Cavitary Lung Disease: Lessons from Two Decades of Experience

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Abstract

Objective: To describe patient characteristics, indications for surgery, operative techniques, perioperative outcomes, and long-term results, thereby contributing local evidence to guide future surgical management in similar high-burden settings.

Methods: This retrospective study was conducted at the Department of Thoracic Surgery, Services Hospital, Lahore, Pakistan, reviewing all patients who underwent surgery for pulmonary fungal or cavitary lung diseases between January 2005 and December 2024. Of 580 patients evaluated, 415 met the inclusion criteria for surgical intervention. Data regarding demographics, comorbidities, operative details, postoperative complications, and long-term outcomes were analyzed using SPSS version 26.

Results: Among the 415 operated patients, 271 (65.3%) were males and 144 (34.7%) females, with a mean age of 45.1 ± 13.4 years. A history of prior pulmonary tuberculosis was present in 250 patients (60.2%), hepatitis C in 183 (44%), and diabetes mellitus in 144 (34.6%). Lobectomy was the most frequently performed procedure (58.1%), followed by segmentectomy (17.3%) and cavernostomy (12.8%). The major postoperative complications included prolonged air leak (8.7%), empyema (5.3%), and bronchopleural fistula (3.4%). The overall in-hospital mortality rate was 2.4%. At follow-up, 92% of patients achieved complete cessation of hemoptysis and marked symptomatic improvement.

Conclusion: Surgical management of pulmonary fungal and cavitary lung diseases is safe and effective when performed in experienced centers. Despite technical challenges, especially in post-tuberculous lungs, operative intervention provides durable control of symptoms and excellent long-term outcomes with acceptable morbidity and mortality.

Keywords: Pulmonary aspergilloma, Cavitary lung disease, Fungal lung infection, Thoracic surgery, Lobectomy.

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Introduction

Pulmonary disease caused by filamentous fungi, most commonly Aspergillus species, presents a wide clinical spectrum ranging from asymptomatic colonization and simple aspergilloma to chronic cavitary disease and life-threatening invasive pulmonary aspergillosis. The global burden of pulmonary aspergillosis has increased with the rising prevalence of post-tuberculosis lung cavities, chronic obstructive pulmonary disease, and immunocompromised states, especially in developing countries where tuberculosis remains endemic.[1,2] In such settings, aspergillosis continues to be a significant cause of recurrent hemoptysis, chronic infection, and respiratory morbidity.

Surgical management retains a vital role in the treatment of localized pulmonary fungal disease. Resection or cavity-directed procedures are often indicated for massive or recurrent hemoptysis, failure of medical therapy, or to eradicate persistent fungal cavities.[3,4] Advances in perioperative care, antifungal therapy, and surgical techniques have led to marked improvements in outcomes, with contemporary reports showing perioperative mortality rates below 5% in experienced centers.[5-7] However, surgery for aspergilloma remains technically

demanding due to dense pleural adhesions, distorted hilar anatomy, and poor pulmonary reserve, especially in patients with post-tuberculous or fibrotic lungs.[8,9] Such challenges contribute to higher rates of prolonged air leak, empyema, and postoperative respiratory compromise in complex cases.

The clinical presentation and operative risk are strongly influenced by the type of aspergilloma. Simple aspergillomas occurring in an intact parenchyma are associated with favorable outcomes following limited resections, while complex or "secondary" aspergillomas developing in previously diseased or destroyed lungs carry substantially higher morbidity.[10] Careful patient selection, optimization of pulmonary function, and the use of perioperative antifungal prophylaxis are essential to achieving good results.

In Pakistan, where tuberculosis remains highly prevalent, post-tuberculous cavitary disease provides a fertile substrate for Aspergillus colonization. Institutional reports from the region have demonstrated that surgical resection, when performed in specialized thoracic units, achieves effective symptom control and long-term cure with outcomes comparable to international experience.[11,12] Nevertheless, there remains limited long-term data from high-volume centers documenting operative management strategies and outcomes for fungal and cavitary lung diseases in our setting.

This study aims to review and analyze the 20-year experience of the Department of Thoracic Surgery at Services Hospital Lahore (2005–2024) in the operative management of aspergilloma, invasive fungal disease, and other cavitary pulmonary conditions. The objective is to describe patient characteristics, indications for surgery, operative techniques, perioperative outcomes, and long-term results, thereby contributing local evidence to guide future surgical management in similar high-burden settings.

Methods

Study Design and Setting: This retrospective observational review study was conducted at the Department of Thoracic Surgery, Services Hospital, Lahore; a high-volume tertiary-care and teaching center that serves as a regional referral unit for complex thoracic diseases. The study reviewed the institutional experience in the operative management of pulmonary aspergilloma, invasive fungal disease, and other cavitary lung lesions over 20 years (January 2005 to December 2024).

The department routinely maintains detailed surgical logs, patient records, and electronic data, allowing for comprehensive retrieval of demographic, clinical, operative, and follow-up information.

Patient Selection: All adult patients (≥ 18 years) who underwent surgical intervention for radiologically and/or microbiologically confirmed pulmonary fungal or cavitary lung disease during the study period were included. Patients with incomplete or missing clinical records, massive bilateral fungal or cavitatory disease, FEV1 < 1 liter or poor cardio-pulmonary reserve for surgery, unfit for general anesthesia, active, untreated pulmonary tuberculosis and detection of malignancy in the post-operative duration were excluded from the study.

Patients were stratified into four diagnostic categories based on radiological, operative, and histopathological findings: Simple aspergilloma – a single, thin-walled cavity containing a mobile fungal ball in an otherwise preserved lung parenchyma. Complex aspergilloma – cavity formation within a fibrotic, post-tuberculous, or structurally destroyed lung. Invasive fungal disease – tissue invasion confirmed histopathologically, typically associated with necrotic or immunocompromised lungs. Other cavitary lesions – non-fungal, post-infectious, or chronic suppurative cavities requiring resection or debridement.

A total of 580 patients were evaluated for fungal and cavitary lung disease, of whom 415 met the inclusion criteria and underwent surgical management.

Preoperative Evaluation: All patients underwent a comprehensive preoperative assessment, including:

- Contrast-enhanced CT chest to delineate the extent of disease, pleural adhesions, and vascular anatomy.
- Routine blood investigations (complete blood count, liver and renal function tests).
- Pulmonary function testing (PFTs) to assess operative risk, particularly in post-tuberculous or fibrotic lungs.
- Bronchoscopy for airway assessment and exclusion of endobronchial lesions when indicated.
- Microbiological and histopathological studies (sputum, bronchoalveolar lavage, or intraoperative biopsy) to confirm fungal etiology.

Surgical Technique and Perioperative Management: All operations were performed by consultant thoracic surgeons under general anesthesia with single-lung ventilation. The standard posterolateral thoracotomy was used in the majority of cases; video-assisted thoracoscopic surgery (VATS) was selectively employed in the later years for localized lesions without dense adhesions.

Dense pleural adhesions, commonly encountered in post-tuberculous and complex cases, were managed through a mixture of blunt, sharp and extrapleural dissection. Depending on the extent of the disease and pulmonary reserve, the following procedures were

performed: lobectomy (most frequent procedure), segmentectomy or wedge resection, pneumonectomy in extensive unilateral disease, cavernostomy or decortication in patients with limited functional reserve or pleural involvement.

Intraoperative fungal cultures were routinely obtained. Intraoperative hemostasis was meticulously achieved, given the frequent presence of hypertrophied collateral vessels and adhesions.

All patients received perioperative antifungal therapy —most commonly voriconazole or itraconazole—for 3 months postoperatively, tailored according to microbiological results and clinical course.

Postoperative Care and Follow-up: Patients were extubated immediately after surgery, where feasible, and managed in a high-dependency or intensive care setting for at least 24 to 48 hours. Chest tubes were maintained until full lung re-expansion and drainage reduction.

Follow-up evaluations were performed at 2 weeks, 1 month, 3 months, and subsequently every 6 months, including clinical assessment, chest imaging, and evaluation for recurrence or complications. Long-term data were collected on symptom relief, recurrence of hemoptysis, and survival.

Outcome Measures: Primary outcomes included; control or cessation of hemoptysis, Incidence of major postoperative complications, such as prolonged air leak (>7 days), empyema, bronchopleural fistula (BPF), or respiratory failure. Secondary outcomes included; length of hospital stay, 30-day operative mortality, long-term recurrence of fungal infection and symptom improvement and overall survival.

Statistical Analysis: All data were analyzed using IBM SPSS Statistics version 26. Continuous variables were presented as mean ± standard deviation (SD) or median (interquartile range), as appropriate, while categorical variables were summarized as frequencies and percentages.

Comparative analysis between simple and complex aspergilloma and invasive versus non-invasive disease groups was performed using: Student's t-test or Mann – Whitney U test for continuous variables, and chi-square (χ^2) or Fisher's exact test for categorical variables.

Multivariate logistic regression was applied to identify independent predictors of postoperative complications, including age, comorbidities, procedure type, and disease category. A p-value < 0.05 was considered statistically significant.

Results

A total of 580 patients presented between January 2005 and December 2024 with fungal and cavitary lung diseases, of whom 415 patients underwent surgical management at the Department of Thoracic Surgery, Services Hospital, Lahore.

Among the 415 operated cases, there were 271 males (65.3%) and 144 females (34.7%), with a mean age of 45.1 ± 13.4 years (range: 18–74 years).

A history of previous pulmonary tuberculosis was present in 250 patients (60.2%), while hepatitis C infection was documented in 183 patients (44.1%). Chronic obstructive pulmonary disease (COPD) and diabetes mellitus were noted in 56 (13.5%) and 144 (34.6%) patients, respectively. Many patients had multiple comorbidities. A total of 72 patients (17.3%) were current or former smokers.

The predominant presenting symptom was hemoptysis, seen in 374 patients (90.1%), including 149 (35.9%) with at least one episode of massive hemoptysis (>300 mL/24 h). Other common symptoms included chronic cough (182; 43.9%), dyspnea (97; 23.4%), and low-grade fever (54; 13.0%).

Table 1: *Baseline Demographic and Clinical Characteristics (N=415)*

Variables		n (%) or Mean ± SD
Age (Years)		45.1 ± 13.4 (range: 18–74)
Sex		
	• Male	271 (65.3)
	• Female	144 (34.7)
History Of Pulmonary Tuberculosis		250 (60.2)
Smoking History		72 (17.3)
Comorbidities		
	• Hepatitis C	183(44.1%)
	• COPD	56 (13.5)
	• Diabetes mellitus	144 (34.6)
	• Hypertension	48 (11.6)
Primary Symptom		
	• Hemoptysis	374 (90.1)
	• Massive hemoptysis (>300 mL/24 h)	149 (35.9)
	• Chronic cough	182 (43.9)
	• Dyspnea	97 (23.4)
	• Fever	54 (13.0)
Duration Of Symptoms (Months)		15.6 ± 10.2
Mean Preoperative FEV_1 (% Predicted)		60.7 ± 12.9

The mean duration of symptoms before surgery was 15.6 ± 10.2 months. Preoperative pulmonary function testing (available in 362 patients) showed a mean FEV_1 = 60.7 ± 12.9% predicted, indicating moderate functional limitation in most cases.

Chest CT revealed a fungal ball within a thick-walled cavity in 273 patients (65.8%), and destroyed or fibrotic lung with multiple cavities in 142 (34.2%).

Right-sided disease predominated (226; 54.5%), followed by left-sided (176; 42.4%), and bilateral involvement in 13 (3.1%).

Classification based on imaging and histopathology diagnosis were; simple aspergilloma: 128 (30.8%), complex aspergilloma: 211 (50.8%), invasive fungal disease: 42 (10.1%), other cavitary lesions (non-fungal): 34 (8.2%)

Microbiological or histopathological confirmation of Aspergillus spp. was achieved in 342 cases (82.4%).

Table 2: *Radiologic and Pathologic Disease Classification*

Parameter		n (%)
Disease Type	Simple aspergilloma	128 (30.8)
	Complex aspergilloma	211 (50.8)
	Invasive fungal disease	42 (10.1)
	Other post-infectious cavitary lesions	34 (8.2)
Side of Disease	• Right lung	226 (54.5)
	• Left lung	176 (42.4)
	• Bilateral	13 (3.1)
	Confirmed Aspergillus spp. (histopathology/microbiology)	342 (82.4)

The posterolateral thoracotomy approach was used in 367 patients (88.4%), VATS in 34 (8.2%), and combined approach, VATS converted to open in 14 (3.4%).

Type of procedure performed were; lobectomy in 192 (46.3%) patients followed by segmentectomy/Wedge resection in 73 (17.6%) patients, pneumonectomy in 51(12.3%), cavernostomy or open-window thoracostomy in 49 (11.8%), and decortication with cavity deroofing in 50 (12.0%) patients.

Dense pleural adhesions were encountered in 327 patients (78.8%), and destroyed lung was noted in 98 (23.6%). The mean operative time was 182 ± 52 minutes, and the mean estimated blood loss was 740 ± 340ml. Intraoperative complications (mostly vascular injury or air-entry difficulty) occurred in 27 patients (6.5%), all managed without intraoperative mortality.

Table 3: *Operative Procedures and Intraoperative Findings*

Variable		n (%) or Mean ± SD
Surgical Approach	• Posterolateral thoracotomy	367 (88.4)
	• VATS	34 (8.2)
	• Combined/extended approach	14 (3.4)
Type Of Procedure	• Lobectomy	192 (46.3)
	• Segmentectomy/ Wedge resection	73 (17.6)
	• Pneumonectomy	51 (12.3)
	• Cavernostomy/ Open-window thoracostomy	49 (11.8)
	• Decortication with cavity deroofing	50 (12.0)
Dense Pleural Adhesions		327 (78.8)
Destroyed Lung		98 (23.6)
Mean Operative Time (Minutes)		182 ± 52
Estimated Blood Loss (ml)		740 ± 340
Intraoperative Complications		27 (6.5)

The mean duration of chest-tube drainage was 4.9 ± 2.5 days, and the mean postoperative hospital stay was 9.2 ± 4.6 days. Overall postoperative morbidity occurred in 123 patients (29.6%), distributed as follows: prolonged air leak (>7 days) observed in 49 (11.8%) patients, empyema in 21 (5.1%), bronchopleural fistula in 15 (3.6%), respiratory failure or re-intubation in 23 (5.5%), wound infection in 19 (4.6%), and postoperative hemorrhage needing re-exploration in 7 (1.7%) patients. The 30-day mortality rate was 3.4% (14 patients), predominantly among those undergoing pneumonectomy for destroyed or invasive disease.

Morbidity was significantly higher in complex aspergilloma and invasive fungal disease (38.7%) compared with simple aspergilloma (15.6%) ($p = 0.002$). Prolonged air leak and BPF were more frequent in patients with preoperative $FEV_1 < 55\%$ ($p = 0.01$) and in those with extensive pleural adhesions ($p = 0.03$).

Follow-up data were available for 367 patients (88.4%), with a median follow-up of 48 months (range 6–180 months).

Peri- and postoperative antifungal therapy was administered to 381 patients (91.8%)—most commonly voriconazole (237; 57.1%), itraconazole (108; 26.0%), and amphotericin B (36; 8.7%). At the last follow-up, complete symptom relief was achieved in 324 patients (88.3%), partial relief in 30 (8.2%), and persistent or

recurrent symptoms in 13 (3.5%). Radiologic or microbiologic recurrence of fungal disease occurred in 19 patients (5.2%), mostly after cavernostomy or limited resection. Recurrent hemoptysis was documented in 17 (4.6%), commonly from contralateral or residual disease. Five-year and ten-year survival rates were 93.1% and 85.4%, respectively.

Table 4: *Postoperative Outcomes and Long-Term Follow-up*

Outcome		n (%) or Mean±SD
Duration Of Chest Tube	Drainage (Days)	6.9 ± 3.5
Length Of Hospital Stay	Days	11.2 ± 5.6
Postoperative Morbidity	Overall	123 (29.6)
	• Prolonged air leak (>7 days)	49 (11.8)
	• Empyema	21 (5.1)
	• Bronchopleural fistula	15 (3.6)
	• Respiratory failure/re - intubation	23 (5.5)
	• Wound infection	19 (4.6)
	• Postoperative hemorrhage/re - exploration	7 (1.7)
30-Day Mortality		14 (3.4)
Median Follow - Up Duration	**Months**	**48 (range: 6–180)**
Adjuvant Antifungal Therapy	• Voriconazole	237 (57.1)
	• Itraconazole	108 (26.0)
	• Amphotericin B	36 (8.7)
Complete Symptom Relief		324(88.3)*
Recurrence Of Fungal Disease		19 (5.2)
Recurrent Hemoptysis		17 (4.6)
Five-Year Survival Rate		93.1%
Ten-Year Survival Rate		85.4%

On multivariate logistic regression, significant predictors of postoperative complications included: complex aspergilloma (OR = 2.4, p = 0.006), pneumonectomy (OR = 3.1, p = 0.008), FEV_1 < 50% predicted (OR = 2.2, p = 0.02), and presence of dense pleural adhesions (OR = 1.9, p = 0.04)

Surgical management of pulmonary aspergilloma and cavitary fungal disease in this large 20-year series achieved excellent long-term symptom control and low mortality (3.4%). Overall morbidity was 29.6%, mainly related to prolonged air leak and empyema. Complex aspergilloma, extensive pleural adhesions, and poor preoperative pulmonary reserve were major predictors of complications. Lobectomy and anatomic segmentectomy offered durable cure in most cases, whereas cavernostomy provided palliation in high-risk or poor-reserve patients but carried higher recurrence rates.

Discussion

The present study represents one of the largest single-institution experiences from Pakistan evaluating the operative management of pulmonary aspergilloma, invasive fungal disease, and related cavitary lung conditions over a two-decade period. Our findings confirm that surgical treatment remains a cornerstone of management in localized fungal lung disease, achieving excellent symptom control and low mortality when performed in specialized thoracic units.

In our cohort of 415 surgically managed patients, the mean age was 45 years, with a male predominance (65.3%). This demographic profile is comparable to regional studies from high tuberculosis (TB) burden countries, where post-tuberculous cavitary disease remains the major predisposing factor for aspergilloma formation.[2,13,14] A history of prior pulmonary tuberculosis was present in 60.2% of our patients—closely mirroring reports from Karachi (Pakistan) by Rizvi et al., who found 63% of aspergilloma patients with prior TB,[15] and consistent with Indian series reporting TB rates between 55–70%.[16,17] Comorbid conditions such as diabetes mellitus (34.6%) and hepatitis C infection (44%) were frequent in our population, reflecting the high prevalence of these conditions in Pakistan and their potential contribution to postoperative morbidity. The relatively young age at presentation compared to Western data (where mean age often exceeds 55 years) may be attributed to earlier onset of TB and environmental exposure in developing regions.[18]

The majority of patients underwent surgery for recurrent or massive hemoptysis, a finding consistent with international data where hemoptysis is reported as the dominant indication in over 70% of cases.[5,10] Lobectomy was the most commonly performed procedure, followed by segmentectomy and cavernostomy. Although minimally invasive (VATS) approaches were introduced in later years, dense adhesions and destroyed lung parenchyma continued to necessitate open thoracotomy in most cases—a trend also seen in similar series from India, China, and South Korea.[12,19] Complex aspergillomas comprised the majority of our cohort and were associated with higher intraoperative blood loss, prolonged air leak, and increased postoperative complications. These findings align with prior studies showing that complex or secondary aspergillomas, often arising in fibrotic or post-tuberculous lungs, carry higher sur-

gical risk than simple forms.[20,21]

Our overall postoperative complication rate (approximately one-third of patients) and prolonged air leak incidence are comparable to those reported in other high-volume thoracic centers.[7,8,12] The rates of empyema and bronchopleural fistula, though notable, were significantly lower in later years, likely due to improvements in perioperative care, use of antifungal prophylaxis, and refined surgical technique. The 30-day mortality remained below 5%, consistent with international standards and supporting the safety of surgery in carefully selected patients.[22,23] Cavernostomy and decortication offered good palliation in patients with limited pulmonary reserve who were poor candidates for anatomical resection, echoing findings from Kim et al. and Farid et al., who demonstrated favorable symptom relief and acceptable recurrence rates with limited procedures in high-risk groups.[10,24]

Long-term follow-up revealed excellent control of hemoptysis and symptomatic improvement in the majority of patients, with recurrence rates below 10%. These outcomes are in line with studies from Europe and Japan reporting durable benefits after complete resection and postoperative antifungal therapy.[25] Our protocol of routine postoperative antifungal prophylaxis (voriconazole or itraconazole) for 3 months may have contributed to the low recurrence observed, as supported by similar regimens recommended in recent guidelines.

In developing countries such as Pakistan, the dual burden of tuberculosis and chronic pulmonary disease provides an ongoing reservoir for fungal colonization. Despite limited resources, our experience shows that with appropriate surgical expertise, outcomes can match those of advanced international centers. Previous national reports, including those from Karachi and Rawalpindi, have highlighted similar success with surgery as the definitive modality for localized aspergilloma.[15] Our study further strengthens this evidence base through its large sample size, extended follow-up, and comprehensive documentation of complications and outcomes.

The retrospective design and reliance on hospital records pose inherent limitations, including potential data omissions and loss to long-term follow-up. Moreover, non-operative cases were excluded, limiting generalization to the broader aspergillosis population. Nonetheless, this large-scale dataset provides valuable insight into surgical management trends, outcomes, and evolving practices over two decades in a high TB-burden setting.

Conclusion

Surgical intervention remains the definitive treatment for localized pulmonary aspergilloma and chronic cavitary fungal disease, particularly in patients presenting with recurrent hemoptysis or failure of medical therapy. Outcomes in our 20-year institutional experience demonstrate low mortality and durable symptom control comparable to international standards. Continued emphasis on early referral, multidisciplinary management, and postoperative antifungal therapy is essential to optimize outcomes in resource-limited, high-prevalence regions.

Ethical Approval: The IRB/EC approved this study via letter no. IRB/2025/1696/SIMS dated November 07, 2025.

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Authors' Contribution

MSN: Conception.

ZS: Design of the work.

HI, SR, MSM: Data acquisition, analysis, or interpretation.

ZS, HI, SR, MSM: Draft the work.

MSN: Review critically for important intellectual content.

All authors approve the version to be published.

All authors agree to be accountable for all aspects of the work.

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