ORIGINAL ARTICLE

Physiological Predictors of Postoperative Pulmonary Complications in Thoracic Surgery Patients with Cardiovascular Comorbidities: A Cross-Sectional Clinical Study

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ABSTRACT
Background: Postoperative pulmonary complications (PPCs) are among the most frequent causes of morbidity and prolonged hospitalization following thoracic surgery, particularly in patients with coexisting cardiovascular diseases. Identifying physiological predictors of PPCs can guide preoperative optimization and improve surgical outcomes.
Objective: To evaluate key physiological predictors associated with the development of postoperative pulmonary complications in thoracic surgery patients with cardiovascular comorbidities.
Methods: This cross-sectional clinical study was conducted at the Department of Thoracic Surgery, MTI–Hayatabad Medical Complex, Peshawar, and THQ Hospital, Kallar Syeda, from March 2022 to March 2023. A total of 120 patients undergoing elective thoracic surgeries were included. Preoperative assessments included spirometry (FEV_1), arterial blood gases (PaO_2, $PaCO_2$), oxygen saturation (SpO_2), ejection fraction (EF), and body mass index (BMI). All patients were followed for seven days postoperatively for PPCs such as atelectasis, pneumonia, bronchospasm, and respiratory failure. Data were analyzed using SPSS v26, with logistic regression applied to determine independent predictors.
Results: The incidence of PPCs was 32.5%. Patients with PPCs had significantly lower mean FEV_1 (58.7 ± 12.1%), EF (46.5 ± 7.4%), and SpO_2 (91.6 ± 3.2%) and higher $PaCO_2$ levels (48.6 ± 6.1 mmHg). Multivariate analysis identified $FEV_1 < 60\%$ predicted (OR 4.12, p = 0.001), EF < 50% (OR 3.56, p = 0.003), BMI > 30 kg/m² (OR 2.21, p = 0.038), and $PaCO_2 > 45$ mmHg (OR 2.94, p = 0.011) as independent predictors of PPCs.
Conclusion: Reduced pulmonary capacity, impaired cardiac function, obesity, and hypercapnia are strong physiological predictors of postoperative pulmonary complications. Incorporating these parameters into preoperative risk assessments can enhance patient safety and postoperative outcomes.
Keywords: Thoracic surgery, postoperative pulmonary complications, cardiovascular comorbidities, FEV_1, ejection fraction, obesity, hypercapnia.

INTRODUCTION

Thoracic surgeries, including lobectomy, pneumonectomy, and mediastinal procedures, carry a substantial risk of postoperative pulmonary complications (PPCs) due to their direct involvement with respiratory mechanics[1]. These complications, such as atelectasis, pneumonia, bronchospasm, and respiratory failure, significantly increase hospital stay, morbidity, and mortality. While advances in surgical techniques and perioperative care have reduced overall mortality, PPCs remain a persistent challenge, particularly in patients with pre-existing cardiovascular comorbidities[2,3].

Cardiovascular disorders such as ischemic heart disease, chronic heart failure, and hypertension alter hemodynamic stability and compromise tissue oxygenation[4]. During thoracic surgery, these patients face additional physiological stress from single-lung ventilation, reduced functional residual capacity, and postoperative pain, all of which may impair effective respiration and coughing. The combined burden of cardiac dysfunction and altered pulmonary mechanics creates a high-risk environment for postoperative pulmonary compromise[5].

Preoperative identification of physiological predictors—such as forced expiratory volume in one second (FEV_1), arterial blood gas (ABG) values, ejection fraction (EF), and oxygen saturation (SpO_2)—is crucial to predict which patients are most likely to develop PPCs[6]. These measurable parameters provide insights into the functional reserve of both respiratory and cardiovascular systems, enabling clinicians to plan perioperative interventions more effectively[7,8].

Despite the growing understanding of PPCs, there is limited clinical data focusing on the interaction between pulmonary and cardiac physiology in thoracic surgery patients within the South Asian population. This study therefore aims to evaluate key physiological predictors of postoperative pulmonary complications among thoracic surgery patients with cardiovascular comorbidities. Identifying such predictors will help refine risk stratification models, improve surgical outcomes, and enhance perioperative management strategies[9].

MATERIALS AND METHODS

Study Design and Setting: This cross-sectional clinical study was conducted at two major centers: the Department of Thoracic Surgery, Medical Teaching Institute (MTI) – Hayatabad Medical Complex, Peshawar, and the Department of Surgery, Tehsil Headquarter (THQ) Hospital, Kallar Syeda, Pakistan. Both hospitals are recognized tertiary care facilities with specialized thoracic and cardiovascular units that receive a wide range of surgical referrals. The study was carried out over a period of one year, from March 2022 to March 2023, to ensure adequate sample collection and postoperative follow-up.

Study Population and Sample Size: A total of **120 patients** who underwent elective thoracic surgery were included in the study using a consecutive sampling method. The study population consisted of both male and female patients aged between 18 and 75 years, all of whom had at least one confirmed cardiovascular comorbidity such as ischemic heart disease, chronic heart failure, or hypertension. The selected patients represented a diverse group in terms of demographic and clinical characteristics, allowing for comprehensive analysis of preoperative physiological parameters and their relationship to postoperative outcomes.

Inclusion and Exclusion Criteria: Patients were included if they were adults above 18 years of age, scheduled for elective thoracic surgical procedures such as lobectomy, pneumonectomy, or

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mediastinal mass removal, and had at least one cardiovascular comorbidity verified through medical records or diagnostic investigations. Patients were excluded if they were undergoing emergency thoracic operations, had chronic infectious pulmonary diseases like tuberculosis or bronchiectasis, were on long-term ventilatory support, or were unable or unwilling to provide informed consent. Those who were lost to follow-up during the postoperative monitoring period were also excluded.

Preoperative Assessment: All enrolled patients underwent a detailed preoperative physiological and clinical evaluation. Pulmonary function tests (PFTs) were performed using a calibrated digital spirometer to determine the forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC). Arterial blood gas (ABG) analysis was carried out to assess PaO_2, $PaCO_2$, and pH, providing insight into baseline respiratory efficiency. Oxygen saturation (SpO_2) was measured using pulse oximetry while the patient was breathing room air. Cardiac function was evaluated through **transthoracic** echocardiography to measure the left ventricular ejection fraction (EF). Additionally, anthropometric measurements such as height and weight were taken to calculate the body mass index (BMI). All comorbidities, including hypertension, ischemic heart disease, and chronic heart failure, were documented through patient history, ECG, and echocardiographic reports.

Postoperative Monitoring and Outcome Assessment: All patients were closely monitored for seven days postoperatively for the development of pulmonary complications. The complications assessed included atelectasis (confirmed by chest radiography and clinical findings), pneumonia (diagnosed based on fever, leukocytosis, and radiographic infiltrates), respiratory failure (defined as the need for prolonged or repeated ventilatory support), and bronchospasm (characterized by wheezing and hypoxemia requiring medical management). Any patient presenting with one or more of these complications within the first postoperative week was classified as having developed a postoperative pulmonary complication (PPC).

Ethical Considerations: The study protocol was reviewed and approved by the Institutional Review Board (IRB) of MTI – Hayatabad Medical Complex, Peshawar. Written informed consent was obtained from every participant prior to inclusion in the study, and patient confidentiality was maintained throughout the research process according to the Declaration of Helsinki guidelines.

Statistical Analysis: Data were analyzed using Statistical Package for Social Sciences (SPSS) version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables such as age, FEV_1, EF, BMI, PaO_2, and $PaCO_2$ were expressed as mean ± standard deviation (SD), whereas categorical variables including gender, type of comorbidity, and occurrence of PPCs were presented as frequencies and percentages. Independent t-tests were used to compare mean differences between patients with and without postoperative pulmonary complications. Chi-square tests were applied for categorical comparisons, while multivariate logistic regression analysis was performed to identify independent physiological predictors associated with PPCs. A p-value of less than 0.05 was considered statistically significant.

This structured approach ensured reliable data collection, accurate assessment of pulmonary and cardiovascular parameters, and valid statistical interpretation to establish the physiological predictors of postoperative pulmonary complications in thoracic surgery patients with cardiovascular comorbidities.

RESULTS

A total of 120 patients who underwent elective thoracic surgeries were included in the final analysis. The study group comprised 85 males (70.8%) and 35 females (29.2%), with an overall mean age of 57.2 ± 9.6 years. Among all participants, 39 patients (32.5%) developed postoperative pulmonary complications (PPCs), while 81 patients (67.5%) had an uneventful postoperative recovery.

Baseline Demographic and Clinical Characteristics: Table 1 presents the demographic and physiological characteristics of the study population. Patients who developed PPCs were significantly older (59.8 ± 10.7 years) compared to those without complications (55.4 ± 9.2 years, p = 0.041). Gender distribution was similar between the two groups, with males forming the majority in both.

The mean body mass index (BMI) was notably higher in the PPC group (31.2 ± 4.3 kg/m²) than in the non-PPC group (27.8 ± 3.9 kg/m², p = 0.008). In terms of cardiovascular function, patients who experienced PPCs had a markedly lower ejection fraction (EF) (46.5 ± 7.4%) compared with those without complications (54.2 ± 6.3%, p < 0.001).

Pulmonary function tests demonstrated that patients with PPCs had significantly reduced forced expiratory volume in one second (FEV_1) values (58.7 ± 12.1% predicted) relative to those without PPCs (73.5 ± 10.5%, p < 0.001). Moreover, arterial blood gas (ABG) analysis revealed lower PaO_2 and higher $PaCO_2$ among patients who developed PPCs, indicating preoperative hypoxemia and hypercapnia.

Table 1. Baseline Demographic and Physiological Characteristics of the Study Population

Parameter	With PPCs (n = 39)	Without PPCs (n = 81)	p-value
Age (years)	59.8 ± 10.7	55.4 ± 9.2	0.041
Male (%)	74.3	68.9	0.49
Female (%)	25.7	31.1	0.49
BMI (kg/m²)	31.2 ± 4.3	27.8 ± 3.9	0.008
Ejection Fraction (%)	46.5 ± 7.4	54.2 ± 6.3	<0.001
FEV₁ (% predicted)	58.7 ± 12.1	73.5 ± 10.5	<0.001
PaO₂ (mmHg)	69.8 ± 9.6	83.4 ± 10.8	<0.001
PaCO₂ (mmHg)	48.6 ± 6.1	39.7 ± 5.4	<0.001
SpO₂ (%)	91.6 ± 3.2	95.3 ± 2.1	<0.001

As shown in Table 1, patients with reduced pulmonary and cardiac performance (lower FEV_1, EF, and PaO_2) and higher BMI were more prone to develop postoperative pulmonary complications.

Incidence and Spectrum of Postoperative Pulmonary Complications: Out of the 120 patients, 39 (32.5%) developed at least one postoperative pulmonary complication. Atelectasis was the most common complication, occurring in 18 patients (15%), followed by pneumonia in 11 patients (9%), respiratory failure in 10 patients (8%), and bronchospasm in **7** patients (6%). Some patients experienced more than one complication concurrently, particularly pneumonia with respiratory distress.

Table 2. Frequency and Distribution of Postoperative Pulmonary Complications

Type of Complication	Number of Patients (n)	Percentage (%)
Atelectasis	18	15.0
Pneumonia	11	9.0
Respiratory Failure	10	8.0
Bronchospasm	7	6.0
Total (Patients with ≥1 PPC)	39	32.5

Table 2 indicates that atelectasis and pneumonia were the leading postoperative pulmonary events, contributing to over 70% of the total complications recorded.

Comparative Analysis of Physiological Parameters: When comparing patients with and without PPCs, significant differences were observed in preoperative physiological measures. Patients who developed PPCs exhibited lower FEV_1 and SpO_2 levels, as well as higher $PaCO_2$ levels, indicating poor pulmonary reserve. Similarly, reduced ejection fraction (EF) signified diminished cardiac function, which correlated strongly with postoperative respiratory instability. These findings confirm that impaired preoperative cardiopulmonary status is a major determinant of PPC risk.

Multivariate Logistic Regression of Predictive Variables: A multivariate logistic regression analysis was conducted to identify independent predictors of postoperative pulmonary complications while controlling for potential confounders such as age and gender. The analysis revealed that FEV_1 < 60% predicted, EF < 50%, BMI

> 30 kg/m², and $PaCO_2$ > 45 mmHg were statistically significant independent predictors of PPCs.

Patients with low FEV_1 had 4.12 times higher odds of developing PPCs (*OR = 4.12; 95% CI: 1.89–8.94; p = 0.001*), while those with ejection fraction < 50% had 3.56 times greater risk (*OR = 3.56; 95% CI: 1.52–7.68; p = 0.003*). Obese patients (BMI > 30 kg/m²) had more than double the risk (*OR = 2.21; p = 0.038*), and hypercapnia ($PaCO_2$ > 45 mmHg) increased the likelihood of PPCs nearly threefold (*OR = 2.94; p = 0.011*).

Table 3. Multivariate Logistic Regression Analysis of Predictors of Postoperative Pulmonary Complications

Variable	Odds Ratio (OR)	95% Confidence Interval (CI)	p-value
FEV_1 < 60% predicted	4.12	1.89 – 8.94	0.001
EF < 50%	3.56	1.52 – 7.68	0.003
BMI > 30 kg/m²	2.21	1.04 – 4.67	0.038
$PaCO_2$ > 45 mmHg	2.94	1.26 – 6.81	0.011

Table 3 shows that diminished pulmonary capacity, impaired cardiac function, obesity, and elevated carbon dioxide levels were strong, independent predictors of postoperative pulmonary complications.

The overall incidence of postoperative pulmonary complications among thoracic surgery patients with cardiovascular comorbidities was 32.5%, indicating a high-risk group requiring special perioperative attention. Patients with poor pulmonary function (FEV_1 < 60%), low cardiac ejection fraction (< 50%), elevated BMI, and preoperative hypercapnia were significantly more likely to experience PPCs. These findings highlight the importance of integrating comprehensive cardiopulmonary evaluation into preoperative assessment protocols for thoracic surgery candidates to minimize morbidity and optimize outcomes.

DISCUSSION

This cross-sectional study aimed to identify key physiological predictors of postoperative pulmonary complications (PPCs) in thoracic surgery patients with underlying cardiovascular comorbidities[7]. The results demonstrated that reduced forced expiratory volume (FEV_1), low ejection fraction (EF), elevated body mass index (BMI), and increased $PaCO_2$ levels were strong, independent predictors of PPCs. The overall incidence of PPCs in this study was 32.5%, which is consistent with the global range of 25–40% reported for thoracic procedures involving high-risk patients with cardiopulmonary dysfunction[8,9].

The high incidence of PPCs can be attributed to the combined physiological burden of thoracic surgery and pre-existing cardiac disease. Thoracic surgical procedures inherently disrupt lung mechanics due to factors such as single-lung ventilation, diaphragmatic dysfunction, postoperative pain, and impaired clearance of secretions[10]. In patients with cardiovascular compromise, reduced cardiac output further limits oxygen delivery and impairs respiratory muscle performance, increasing the risk of postoperative hypoxemia and atelectasis[11].

The finding that low preoperative FEV_1 is an independent predictor of PPCs aligns with the results of earlier studies, which identified poor pulmonary reserve as a significant risk factor for postoperative morbidity and prolonged hospitalization[12]. Canet et al. (2015) and Agostini et al. (2021) similarly reported that FEV_1 values below 60% predicted were associated with a three- to fourfold increase in postoperative pulmonary complications. Reduced FEV_1 reflects diminished ventilatory reserve, making it difficult for patients to tolerate intraoperative stress and postoperative ventilation challenges[13,14].

Similarly, low ejection fraction (EF) emerged as a major determinant of pulmonary morbidity. This finding highlights the interdependence of cardiac and respiratory systems. A decreased EF (<50%) results in pulmonary congestion and increased capillary hydrostatic pressure, predisposing to interstitial edema and alveolar fluid accumulation[15,16]. Such patients often exhibit reduced pulmonary compliance, limited diffusion capacity, and a higher likelihood of postoperative respiratory failure. These results are consistent with Sharma et al. (2020), who found a significant correlation between cardiac dysfunction and postoperative pulmonary morbidity in thoracic surgical populations[17].

Obesity (BMI > 30 kg/m²) also played an important role in increasing the risk of PPCs in this study. Obese individuals have a higher functional residual capacity reduction, altered chest wall compliance, and limited diaphragmatic movement, all of which predispose to atelectasis and hypoventilation. Additionally, obesity contributes to systemic inflammation and endothelial dysfunction, which may further impair oxygen exchange and tissue healing postoperatively[18,19].

Elevated $PaCO_2$ (>45 mmHg), a marker of hypoventilation, was also identified as a strong predictor of PPCs. Hypercapnia reflects impaired gas exchange and weakened ventilatory capacity, often seen in patients with chronic obstructive pulmonary disease (COPD) or cardiac insufficiency. Patients with elevated $PaCO_2$ preoperatively are more likely to experience postoperative respiratory depression, prolonged mechanical ventilation, and oxygen dependency[20,21].

In terms of complication type, atelectasis and pneumonia were the most frequently encountered, together accounting for over 70% of PPCs. These results are consistent with Johnson et al. (2018), who reported similar patterns in thoracic surgical cohorts. Atelectasis, often a result of hypoventilation and mucus retention, predisposes to infection, leading to pneumonia. Both complications extend hospital stays and increase the need for intensive care support[22,23].

These findings reinforce the importance of preoperative optimization of pulmonary and cardiac function. Interventions such as incentive spirometry, breathing exercises, pulmonary rehabilitation, optimization of heart failure therapy, and smoking cessation can markedly reduce PPC rates. Furthermore, intraoperative lung-protective ventilation and postoperative physiotherapy should be emphasized to minimize respiratory complications[24].

Overall, this study underscores the need for a multidisciplinary perioperative approach, involving thoracic surgeons, anesthesiologists, pulmonologists, and cardiologists to assess and optimize physiological parameters before surgery. By identifying at-risk patients early, clinicians can tailor anesthetic strategies, adjust fluid management, and ensure proactive respiratory care postoperatively, ultimately improving survival and recovery outcomes[25].

CONCLUSION

This study concluded that impaired pulmonary function (FEV_1 < 60% predicted), reduced cardiac ejection fraction (<50%), obesity (BMI > 30 kg/m²), and hypercapnia ($PaCO_2$ > 45 mmHg) are the most significant physiological predictors of postoperative pulmonary complications in thoracic surgery patients with cardiovascular comorbidities. The findings highlight that patients with poor preoperative cardiopulmonary function constitute a high-risk group requiring enhanced perioperative monitoring and targeted optimization strategies. Early identification and management of these risk factors through comprehensive preoperative assessment, tailored anesthetic techniques, and aggressive postoperative respiratory care can significantly reduce morbidity, shorten hospital stays, and improve overall surgical outcomes. Future prospective studies with larger sample sizes and multi-center participation are recommended to validate these predictors and integrate them into standardized preoperative risk stratification models for thoracic surgery patients in South Asian clinical settings.

Authors' Contributions
IT – Conceptualization, study design, and supervision.
AA – Data collection and methodology development.
AS – Statistical analysis and interpretation of data.
ARH – Literature review and drafting of the manuscript.

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