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Incidence and Risk Factors of Postoperative Pulmonary Complications Following On-Pump Cardiac Surgery

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ABSTRACT

Background: Post operative pulmonary complications (PPCs) are one of the most common complications experienced after cardiac surgery with cardiopulmonary bypass (ONCAB surgery). PPCs also increase the cost for postoperative care due to increased number of days in the hospital and elevated need for critical care For improving patient outcomes, it is crucial to understand and/or improve local incidence patterns and modifiable risk factors.

Objectives: To determine the incidence of PPCs after on-pump cardiac surgery and to evaluate demographic, clinical, and intraoperative risk factors associated with their development.

Methods: Between February 2023 and February 2024, 82 patients who had on-pump cardiac elective or urgent surgeries were included in this observational study. The following data were collected and recorded: demographic characteristics, comorbid conditions, details of the surgery, and respiratory outcomes after the surgery. Pneumonia, pulmonary embolism, pulmonary edema, acute respiratory distress syndrome, atelectasis, prolonged mechanical ventilation, re-intubation, and other Postoperative pulmonary complications PPCs were identified based on clinical and imaging results. Chi-square tests were used for statistical analysis, with a significance level set at the $p<0.05$.

Results: The total occurrences of PPCs were 35.4%. 22% had atelectasis and 18.3% had a pleural effusion. Statistically significant associations of PPCs were shown with older age (>65 years), a history of smoking, and COPD, as well as reduced ejection fraction, prolonged bypass time, intraoperative transfusion, and long postoperative ventilation.

Conclusions: The occurrence of PPCs is common after surgeries which require the presence of a cardiopulmonary bypass, and arise from patient features and surgical stress. Identification of at-risk patients and provision of enhanced early perioperative respiratory services may lower the incidence of PPCs and enhance recovery.

Keywords: *postoperative pulmonary complications, on-pump cardiac surgery, risk factors, atelectasis, cardiopulmonary bypass, respiratory outcomes*

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1. INTRODUCTION

Pulmonary complications after surgeries remain a relevant complication to cardiac surgeries, especially when surgeries require cardiopulmonary bypass. The evolution of techniques in surgery and anesthesia have not made surgery any more

simple- the respiratory system is still weak and will have to endure the stress of extracellular circulation, ventilation via a machine, and long execution times. Consequently, there are ongoing postoperative complications like atelectasis, pneumonia, and pleural effusion [1-3].

The variations in the prevalence of PPCs differ in percentage in literature between 20 to over 50% and depend on specific patient populations and procedural setting. Elderly adults, smokers, and individuals who are overweight or suffer from comorbidities that impact the heart or ones that involve the respiratory system tend to have a higher risk. In addition, it has been shown that some intraoperative variables affect pulmonary outcomes postoperatively, including bypass duration, time spent on cross-clamp, volume of blood and blood products transfused, andintraoperative hypothermia or normothermia [4-6].

Accounting for variations in regional practices and the makeup of patient samples requires consideration of local data when doing focused clinical decision-making and assessing the pre-existing correlations [7-9]. All cardiac units handle different types of comorbidities, surgical techniques, and post-operative management plans, which affect the risk of developing complications related to the lungs. Understanding these behaviors may provide opportunities to enhance perioperative protocols, support the effective allocation of resources, and identify areas to implement preventative measures.

The purpose of this research is to examine the incidence of post-operative pulmonary complications (PPCs) in the first year following on-pump cardiac surgery, and to identify the significant demographic, clinical, and intra-operative factors associated with these complications. The purpose of this study is to identify the most significant predictive factors to tailor perioperative care with the ultimate goal of improving surgical outcomes.

2. METHODOLOGY

This research sought to examine the prevalence and possible predictors of pulmonary complications post-cardiac surgeries involving cardiopulmonary bypass through an observational study approach. The prior study occurred at Sakina Medical Complex Kasur, Pakistan. The study lasted one year starting from February 2023 to February 2024. There were 82 patients who met inclusion criteria and were enrolled in the study.

All adults who were scheduled to receive elective or urgent on-pump cardiac surgeries were included in the study. Such surgeries included, but were not limited to, coronary artery bypass surgeries (CABG), valve surgeries, or other combined procedures. To minimize confounding, patients having off-pump procedures, patients with incomplete perioperative records, and patients with active respiratory infections at the time of surgery were not included. In order to circumvent any possible selection bias, each participant was enrolled one at a time. Information pertaining to the participants' demographics, comorbidities, and clinical features prior to surgery, were extracted from the participants' medical records.

For all cases, the same protocols for anesthesia and cardiopulmonary bypass were standardized and maintained. Specific details, including the total time operated, bypass, and cross clamping, usage of hypothermia, and need for transfusion, were tracked by the surgical and anesthesiology departments. Patients were started on postoperative monitoring in the ICU during which time they were screened for any respiratory complications until discharge or the complications were resolved.

This investigation defined PPCs per clinical and imaging complications already established in the literature. The complications we included were atelectasis, pneumonia, pleural effusion, pulmonary edema, acute respiratory distress syndrome (ARDS), prolonged (>24 hours) mechanical ventilation, and unplanned re-intubation. Verification of the diagnosis relied on the clinical assessment of the patients on a daily basis, as well as, imaging studies of the chest, the degree of oxygenation, and notes made by the attending physicians.

Appropriate statistical analysis were performed following data entry into a structured database. Chi-square analyses were conducted on categorical variables while the continuous variables were summarized into a mean and standard deviation. p-values less than around 0.05 were considered statistically significant.

3. RESULTS

A total of 82 patients who underwent on-pump cardiac surgeries were included in this study's analysis. The analysis included several socio-demographic and preoperative characteristics, which were quite diverse especially in terms of ages and the pre-existing comorbidities, which are critical for evaluating the patients' surgical risk profile for postoperative pulmonary complications (PPCs). The sample population reflected cohorts of cardiac surgery patients that predominantly included males, and there was also a notable incidence of smoking, hypertension, and diabetes.

Table 1. Demographic and Preoperative Characteristics (n = 82)

Variable	Category / Mean ± SD	n (%)
Age (years)	—	62.4 ± 9.8
Age Groups	< 50 years	14 (17.1%)
	50–65 years	42 (51.2%)
	> 65 years	26 (31.7%)
Gender	Male	56 (68.3%)
	Female	26 (31.7%)
BMI (kg/m²)	—	27.6 ± 3.9
Smoking Status	Current smoker	29 (35.4%)
	Former smoker	18 (22.0%)
	Non-smoker	35 (42.6%)
Diabetes Mellitus	Yes	33 (40.2%)
Hypertension	Yes	45 (54.9%)
COPD/Asthma	Present	11 (13.4%)
Left Ventricular Ejection Fraction (%)	—	47.2 ± 8.5
Preoperative Hemoglobin (g/dL)	—	12.8 ± 1.4

The information demonstrated differences in complexity of operations with regard to certain metrics in the intraoperative stage. The most common surgery performed was CABG, followed by surgery for valve replacement and other surgeries that included a combination of other procedures. While the durations of the cardiopulmonary bypass and aortic cross-clamp times were within the expected range for the given surgical procedures, they still had enough of a range to make a comparison of the time-related risk of pulmonary complication of interest.

Table 2. Intraoperative Characteristics

Variable	Category / Mean ± SD	n (%)
Type of Surgery	CABG	48 (58.5%)
	Valve surgery	22 (26.8%)
	Combined procedures	12 (14.7%)
Total Operative Time (min)	—	218 ± 42

Cardiopulmonary Bypass Time (min)	—	106 ± 28
Aortic Cross-Clamp Time (min)	—	78 ± 19
Intraoperative Transfusion	Yes	31 (37.8%)
Hypothermia Used	Yes	69 (84.1%)

Of the 29 patients, 35.4% of them had postoperative pulmonary complications. The most common complications were atelectasis, followed by pneumonia and pleural effusion. Although less common, ARDS and unplanned re-intubation were clinically significant. Higher targeted clinically significant patients were also ARDS and unplanned re-intubation.

Table 3. Incidence of Postoperative Pulmonary Complications (n = 82)

Complication	n (%)
Any PPC (overall incidence)	29 (35.4%)
Atelectasis	18 (22.0%)
Pneumonia	12 (14.6%)
Pleural Effusion	15 (18.3%)
Pulmonary Edema	9 (11.0%)
ARDS	3 (3.7%)
Prolonged Mechanical Ventilation (>24 h)	14 (17.1%)
Re-intubation	5 (6.1%)
Need for Non-Invasive Ventilation	8 (9.8%)

An investigation into risk factors exposed several statistically significant correlational relationships. Increased age, active or previous smoking, COPD, lower left ventricular ejection fraction, long CPB duration, and transfusion intraoperatively showed strong association concerning complication development. On the other hand, although diabetes did display a slightly increased risk, the other factors, gender and diabetes, did not yield statistically significant results.

Table 4. Comparison of Risk Factors in PPC vs No-PPC Groups (n = 82)

Variable	PPC Group (n = 29)	No-PPC Group (n = 53)	p-value
Age > 65 years	15 (51.7%)	11 (20.7%)	**0.004**
Male Gender	21 (72.4%)	35 (66.0%)	0.55
Smoking (current/former)	23 (79.3%)	24 (45.3%)	**0.003**
Diabetes Mellitus	15 (51.7%)	18 (34.0%)	0.11
COPD Present	7 (24.1%)	4 (7.5%)	**0.04**
EF < 40%	12 (41.4%)	10 (18.9%)	**0.02**
CPB Time > 120 min	17 (58.6%)	12 (22.6%)	**<0.001**
Transfusion Required	18 (62.1%)	13 (24.5%)	**<0.001**
Prolonged Ventilation (>24 h)	11 (37.9%)	3 (5.7%)	**<0.001**

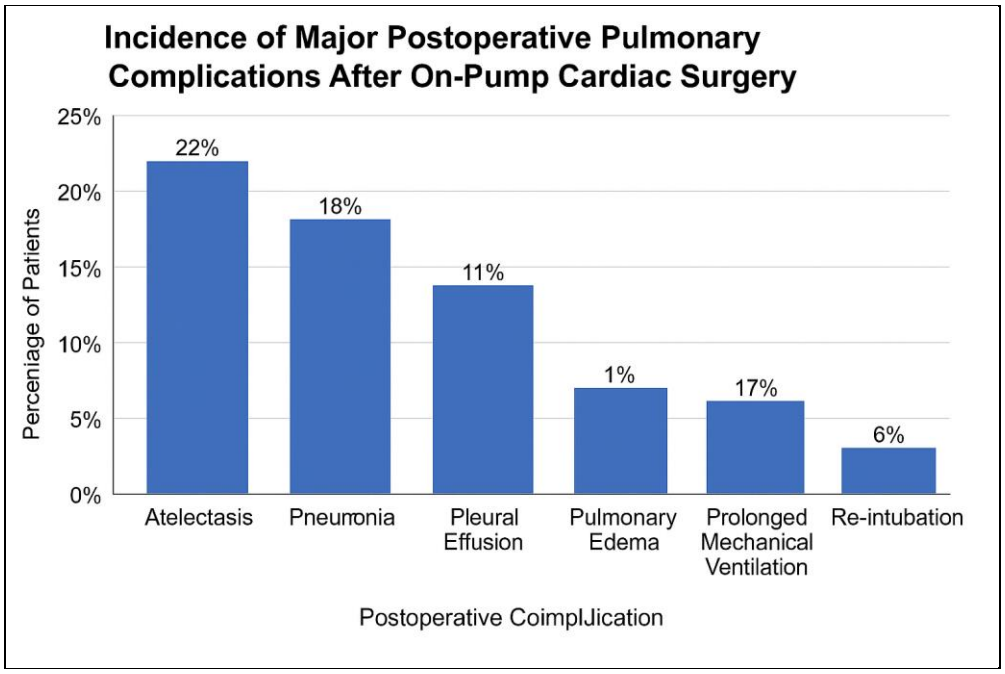

Figure 1. Incidence of Major Postoperative Pulmonary Complications After On-Pump Cardiac Surgery

Figure 1 shows the distribution of major postoperative pulmonary complications among patients who underwent on-pump cardiac surgery (n = 82). Atelectasis (22%) and pleural effusion (18%) were the most common complications, while pneumonia (14.6%), pulmonary edema (11%), and prolonged mechanical ventilation (17%) occurred with moderate frequency. Less frequent but clinically important events included ARDS (3.7%) and re-intubation (6%), reflecting the variability and severity of pulmonary outcomes in this surgical.

4. DISCUSSION

The investigation revealed that the rate of pulmonary complications in the post-operative phase of the on-pump cardiac surgery procedure was 35.4%. This percentage of post-operative pulmonary complications is consistent with the very high rate of pulmonary complications documented in the research publications in the field of cardiac surgery. Atelectasis, pleural effusions, and pneumonia are frequent sequelae linked to the background components, for example, the CPB, excess anesthesia, and the physical meddling with the thoracic area during surgery itself. These results give merit to the probable delicacy of the pulmonary tissues, which continues to be one of the main postoperative worries for patients with cardiac disease [10-12].

It was also previously noted that age is significant as those older than 65 are most likely to experience PPCs. This relationship has also been captured in large cohort studies as age-related factors such as elasticity of lungs, coughing reflex, and the immune system response lead to the poorer postoperative recovery. The data indicates likely improvements for older surgical patients when implementing additional, intensive, perioperative respiratory optimization [13-15].

The correlation between the smoking history and the PPCs is well documented and correlates with the literature that notes the long impact chronic smoking has on airway reactivity, the cough ability to clear secretions and oxygen delivery postoperatively. At the same time, the lower the preoperative ejection fractions, the more likely the patients were to develop pulmonary complications. This may reflect the relationship of the drop in cardiac output and pulmonary congestion, which is likely to be resulted in the lower functional reserve and greater risk of respiratory failure [16-18].

There were also intraoperative aspects that were also significant as well. Long cardiopulmonary bypass duration was one of the strongest predictors of complications in this cohort as seen in past studies that describe the inflammatory and ischemia reperfusion effects that are associated with longer bypass times. Intraoperative transfusion patients experienced even higher rates of complications which may be attributed to increased inflammatory burden of larger procedures or transfusion-related lung injury. Some impacts of prolonged ventilatory support and the resulting PPCs showcased the interplay of respiratory dependence and the remaining pulmonary compromise [19, 20].

Remarkably, diabetes was not statistically significant in this analysis, although a greater percentage were diagnosed. Several reports indicate that worse glycemic control may increase the risk of certain infections, whereas other reports indicate that such an association may not be independent once one considers the operative stress and other comorbid conditions. This diabetes inconsistency suggests the possibility that the condition may influence PPCs only in association with other factors, rather than acting as a primary driver.

In summary, there is concordance in the findings of the research with risk profiles described in the cardiovascular surgery literature; however, it highlights the significance of the timely identification of high-risk patients, given that the clinical variables can be easily recorded in routine clinical practice. This form of risk assessment allows clinicians to predict possible complications and implement appropriate prophylactic measures as well as to use critical care resources more efficiently.

5. CONCLUSION

COPD, older age, smoking, lower ejection fractions, increased durations of cardiopulmonary bypass, CCU admissions and increased transfusions have all been identified as risk factors associated with increased rates of postoperative pulmonary complications following on-pump cardiac surgery. These findings demonstrate the interaction of patient sensitivity and intraoperative tension concerning respiratory outcomes. Identifying high-risk patients early and implementing perioperative pulmonary care increases the likelihood of improving outcomes and recovery and decreasing the complications

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