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Incidence And Predictors Of Postoperative Pulmonary Complications In Patients Admitted To A Surgical Icu- A Prospective Observational Study.

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Abstract

Background: Postoperative pulmonary complications are important causes of morbidity and mortality following major surgery, particularly among patients requiring postoperative intensive care. PPCs include atelectasis, pneumonia, respiratory failure, bronchospasm, aspiration pneumonitis, pulmonary edema, acute respiratory distress syndrome, and requirement for prolonged or unplanned ventilatory support. Identification of perioperative predictors may facilitate early risk stratification and implementation of preventive strategies. ***Aim:*** To determine the incidence and predictors of postoperative pulmonary complications among patients admitted to the Surgical Intensive Care Unit following surgery. ***Materials and Methods:*** This prospective observational study included 130 adult postoperative patients admitted to the Surgical Intensive Care Unit of a tertiary care teaching hospital. Demographic characteristics, smoking history, comorbidities, ASA physical status, preoperative oxygen saturation, hemoglobin level, type and urgency of surgery, and other relevant preoperative variables were recorded. Intraoperative parameters including duration of surgery, ventilation characteristics, hypoxemia, hypotension, estimated blood loss, blood transfusion, and hemodynamic instability were documented. Patients were prospectively monitored for PPCs and subsequent clinical outcomes. Factors associated with PPCs were initially assessed using appropriate univariate statistical tests, followed by multivariable binary logistic regression to identify independent predictors. A p-value <0.05 was considered statistically significant. ***Results:*** Among 130 patients, 25 developed at least one PPC, giving an incidence of 19.2%. Atelectasis (6.9%) was the most frequent complication, followed by postoperative pneumonia (5.4%) and respiratory failure (4.6%). PPCs were significantly associated with age ≥65 years (p=0.008), smoking (p=0.009), chronic respiratory disease (p=0.005), preoperative SpO_2 <96% (p=0.004), anemia (p=0.006), ASA III/IV status (p=0.003), emergency surgery (p=0.005), and upper abdominal/thoracic surgery (p=0.012). Significant intraoperative factors included duration of surgery >3 hours (p=0.004), hypoxemia (p<0.001), hypotension (p=0.009), blood transfusion (p=0.009), blood loss >500 mL (p=0.011), tidal volume >8 mL/kg predicted body weight (p=0.012), and PEEP <5 cm H_2O (p=0.024). On multivariable analysis, age ≥65 years (aOR 2.31), chronic respiratory disease (aOR 3.12), preoperative SpO_2 <96% (aOR 2.89), emergency surgery (aOR 2.73), surgery >3 hours (aOR 2.64), and intraoperative hypoxemia (aOR 4.18) were independent predictors of PPCs. Patients with PPCs had significantly higher prolonged mechanical ventilation (48.0% vs 13.3%; p<0.001), longer ICU stay (6.8 ± 3.1 vs 3.4 ± 1.8 days; p<0.001), longer hospital stay (14.6 ± 5.2 vs 8.7 ± 3.4 days; p<0.001), and higher in-hospital mortality (16.0% vs 2.9%; p=0.025). ***Conclusion:*** Postoperative pulmonary complications occurred in approximately one-fifth of postoperative SICU patients and were associated with significantly increased morbidity, prolonged ICU and hospital stay, and mortality. Advanced age, chronic respiratory disease, low preoperative oxygen saturation, emergency surgery, prolonged surgery, and intraoperative hypoxemia were independent predictors of PPCs. Early risk stratification, optimization of respiratory status, appropriate intraoperative ventilatory management, prevention of hypoxemia, and close postoperative respiratory surveillance may contribute to improved outcomes in high-risk surgical patients.

Keywords: Postoperative pulmonary complications; Surgical Intensive Care Unit; postoperative respiratory failure; atelectasis; pneumonia.

INTRODUCTION

Postoperative pulmonary complications (PPCs) represent an important cause of morbidity, prolonged hospitalization, intensive care utilization, healthcare expenditure, and mortality among patients undergoing major surgical procedures. PPCs comprise a spectrum of respiratory adverse events occurring after surgery, including atelectasis, pneumonia, respiratory infection, bronchospasm, aspiration pneumonitis, pleural effusion, pulmonary edema, acute respiratory distress syndrome, and postoperative respiratory failure requiring prolonged or unplanned mechanical ventilation. The incidence of these complications varies considerably according to the characteristics of the population studied, type and duration of surgery, urgency of the procedure, anesthetic technique, definitions used, and underlying patient-related risk factors. Globally, PPCs continue to constitute a major challenge in perioperative medicine because their occurrence may have an impact on postoperative outcomes comparable to or greater than that of cardiovascular complications.[1]

General anesthesia itself produces important physiological alterations in respiratory mechanics through reductions in functional residual capacity, impairment of respiratory muscle function, ventilation-perfusion mismatch, and development of atelectasis; radiological atelectasis has been reported in more than 75% of patients receiving general anesthesia with neuromuscular blockade.[1] These physiological effects become clinically important when combined with advanced age, smoking, obesity, pre-existing respiratory disease, reduced functional capacity, prolonged surgery, abdominal or thoracic incisions, emergency surgery, and postoperative immobility.

The landmark ARISCAT study demonstrated that factors including advanced age, low preoperative oxygen saturation, recent respiratory infection, preoperative anemia, upper abdominal or intrathoracic surgery, prolonged duration of surgery, and emergency procedures could predict the development of PPCs.[2] Consequently, systematic identification of high-risk surgical patients has become an essential component of modern perioperative risk assessment.

PPCs are particularly important among patients requiring admission to a surgical intensive care unit (SICU), because this population frequently represents a high-risk subgroup with major surgical stress, multiple comorbidities, hemodynamic instability, prolonged operative duration, substantial blood loss, transfusion requirements, and need for postoperative organ support. In such patients, residual anesthetic effects, postoperative pain, diaphragmatic dysfunction, impaired coughing, reduced lung volumes, retained respiratory secretions, and prolonged recumbency may further increase the likelihood of pulmonary complications. Evidence from perioperative studies has consequently emphasized preventive strategies such as lung-protective ventilation, adequate reversal of neuromuscular blockade, opioid-sparing analgesia, early mobilization, respiratory physiotherapy, and appropriate postoperative respiratory support in selected high-risk patients.[3]

The global clinical importance of prevention is reinforced by systematic evidence showing that several perioperative interventions can reduce the occurrence of PPCs, although the effectiveness varies according to intervention and patient population.[4] In the Indian context, PPCs are equally important because surgical patients may present with delayed disease, anemia, malnutrition, smoking-related respiratory impairment, tuberculosis-related residual lung dysfunction, chronic respiratory disease, and multiple comorbidities that may increase postoperative respiratory risk.

A prospective South Indian study involving 150 patients undergoing abdominal surgery reported PPCs in 24 patients (16%) and identified emergency surgery and cardiac comorbidity as independent predictors; importantly, patients developing PPCs experienced significantly longer ICU and hospital stays and greater mortality.[5] More recent Indian evidence among patients undergoing major oncological surgery has similarly demonstrated a clinically relevant burden of PPCs and emphasized the importance of identifying perioperative risk factors in high-risk surgical populations.[6]

The occurrence of PPCs following surgery therefore reflects a complex interaction between pre-existing patient characteristics, surgical factors, anesthetic management, mechanical ventilation, postoperative pain, and the requirement for critical care support. Early recognition of predictors may enable clinicians to identify patients requiring intensified respiratory monitoring, optimization of ventilation, early physiotherapy, mobilization, appropriate analgesia, and timely non-invasive or invasive respiratory support. Furthermore, standardized assessment of PPCs is essential because variation in definitions and outcome reporting has historically contributed to substantial differences in reported incidence across surgical studies.[7]

Surgical ICU patients provide a particularly relevant population for studying these complications because they are continuously monitored and frequently possess several interacting risk factors for postoperative respiratory deterioration. Determination of the incidence and independent predictors of PPCs in this population could therefore facilitate risk stratification, improve allocation of critical-care resources, guide preventive interventions, and potentially reduce avoidable postoperative morbidity and mortality.

Hence, the present study was undertaken to determine the incidence and predictors of postoperative pulmonary complications in patients admitted to a surgical intensive care unit, with the objective of identifying clinically relevant and potentially modifiable factors associated with adverse pulmonary outcomes.

AIM

To determine the incidence and predictors of postoperative pulmonary complications among patients admitted to the Surgical Intensive Care Unit (SICU) following surgery.

OBJECTIVES

Primary Objective

1. To determine the incidence of postoperative pulmonary complications among patients admitted to the Surgical Intensive Care Unit.

Secondary Objectives

2. To identify the preoperative, intraoperative, and postoperative factors associated with the development of postoperative pulmonary complications.
3. To assess the association of postoperative pulmonary complications with duration of mechanical ventilation, length of ICU stay, length of hospital stay, and in-hospital mortality.

MATERIALS AND METHODS

Study Design

The study was conducted as a prospective observational study.

Study Population

Adult postoperative patients who were admitted to the SICU during the study period and fulfilled the eligibility criteria were included.

Sample Size

The sample size was calculated using the formula:

$n = Z^2pq/d^2$

Where: n = required sample size, Z = 1.96 at 95% confidence level

p = anticipated incidence of postoperative pulmonary complications = 16% (0.16), $q = 1 - p = 0.84$, d = absolute precision = 6.3% (0.063)

Therefore,

$n = (1.96)^2 \times 0.16 \times 0.84 / (0.063)^2$, $n \approx 130$

Hence, a total of 130 patients were included in the study.

Sampling Technique

A consecutive sampling technique was used. All eligible postoperative patients admitted to the SICU were recruited consecutively until the required sample size of 130 was achieved.

INCLUSION CRITERIA

1. Patients aged 18 years and above were included.
2. Patients who underwent major surgical procedures and required postoperative admission to the SICU were included.
3. Patients undergoing elective or emergency surgical procedures were included.
4. Patients who provided written informed consent were included.

EXCLUSION CRITERIA

1. Patients who were mechanically ventilated before surgery were excluded.
2. Patients with active pneumonia or acute respiratory infection at the time of surgery were excluded.
3. Patients with pre-existing acute respiratory distress syndrome were excluded.
4. Patients admitted to the SICU for non-postoperative indications were excluded.
5. Patients with incomplete perioperative clinical records were excluded.
6. Patients or legally authorized representatives who refused consent were excluded.

STUDY PROCEDURE

After enrolment, demographic and clinical details including age, sex, body mass index, smoking history, comorbidities, pre-existing respiratory disease, functional status, and ASA physical status were recorded.

Preoperative parameters including oxygen saturation, hemoglobin level, recent respiratory infection, pulmonary comorbidities, and relevant laboratory investigations were documented.
Surgical characteristics including the indication for surgery, elective or emergency status, anatomical site and type of surgery, and duration of surgery were recorded.

Intraoperative Assessment
Intraoperative anesthetic variables including type and duration of anesthesia, airway management, tidal volume, positive end-expiratory pressure (PEEP), fraction of inspired oxygen, intraoperative oxygen saturation, intravenous fluid administration, blood transfusion, estimated blood loss, vasopressor requirement, and hemodynamic instability were recorded.
Episodes of intraoperative hypoxemia, hypotension, difficult airway management, and other relevant anesthetic complications were documented.

Postoperative Assessment
Following surgery, patients were admitted to the SICU and prospectively monitored for the development of postoperative pulmonary complications.

Respiratory rate, oxygen saturation, oxygen requirement, arterial blood gas parameters, clinical chest findings, chest radiography, and other investigations were assessed whenever clinically indicated.

Postoperative pulmonary complications included atelectasis, pneumonia, respiratory tract infection, bronchospasm, aspiration pneumonitis, clinically significant pleural effusion, pulmonary edema, acute respiratory distress syndrome, postoperative respiratory failure, prolonged or unplanned ventilatory support, and unplanned re-intubation.

STATISTICAL ANALYSIS
Data were entered into Microsoft Excel and analyzed using appropriate statistical software. Continuous variables were expressed as mean ± standard deviation or median with interquartile range, while categorical variables were expressed as frequencies and percentages. The incidence of postoperative pulmonary complications was calculated as a percentage with a 95% confidence interval.

The independent Student's t-test or Mann–Whitney U test was used for continuous variables, as appropriate. The Chi-square test or Fisher's exact test was used to assess categorical variables. Variables associated with PPCs on univariate analysis were entered into a multivariable binary logistic regression analysis to determine independent predictors. Adjusted odds ratios with 95% confidence intervals were calculated. A p-value <0.05 was considered statistically significant.

RESULTS

Table 1. Baseline demographic and clinical characteristics of study participants (N=130)

Variable	Frequency n (%) / Mean ± SD
Age (years)	56.4 ± 14.2
Age ≥65 years	39 (30.0%)
Male	78 (60.0%)
Female	52 (40.0%)
BMI (kg/m²)	24.8 ± 3.9
Current/former smoker	44 (33.8%)
Hypertension	52 (40.0%)
Diabetes mellitus	41 (31.5%)
Chronic respiratory disease	21 (16.2%)
Cardiovascular disease	18 (13.8%)
Preoperative anemia	38 (29.2%)
ASA I	13 (10.0%)
ASA II	68 (52.3%)
ASA III/IV	49 (37.7%)
Emergency surgery	46 (35.4%)

Interpretation: The mean age of the study participants was 56.4 ± 14.2 years, with 30% aged ≥65 years. Hypertension (40.0%), smoking history (33.8%), diabetes mellitus (31.5%), and preoperative anemia (29.2%) were common risk factors. More than one-third of patients belonged to ASA III/IV, indicating a substantial burden of perioperative risk among patients admitted to the SICU.

Table 2. Incidence and distribution of postoperative pulmonary complications (N=130)

Postoperative pulmonary complication	n (%)
Atelectasis	9 (6.9%)
Postoperative pneumonia	7 (5.4%)
Respiratory failure	6 (4.6%)
Pleural effusion requiring intervention	4 (3.1%)
Bronchospasm	3 (2.3%)
Aspiration pneumonitis	2 (1.5%)
Pulmonary edema	2 (1.5%)
ARDS	2 (1.5%)
Unplanned re-intubation	4 (3.1%)
Patients with ≥1 PPC	**25 (19.2%)**
Patients without PPC	**105 (80.8%)**

Overall PPC incidence = 25/130 = 19.2% (95% CI approximately 12.9%–27.1%).
Interpretation: Postoperative pulmonary complications occurred in **19.2%** of patients admitted to the SICU.

Atelectasis was the most frequently observed complication (6.9%), followed by postoperative pneumonia (5.4%) and respiratory failure (4.6%). Thus, approximately one in five postoperative SICU patients developed at least one pulmonary complication.

Table 3. Association of preoperative and surgical factors with development of PPCs

Risk factor	PPC present (n=25)	PPC absent (n=105)	p-value
Age ≥65 years	13 (52.0%)	26 (24.8%)	**0.008**
Smoking history	14 (56.0%)	30 (28.6%)	**0.009**
Chronic respiratory disease	9 (36.0%)	12 (11.4%)	**0.005**
Preoperative SpO_2 <96%	10 (40.0%)	14 (13.3%)	**0.004**
Preoperative anemia	13 (52.0%)	25 (23.8%)	**0.006**
ASA III/IV	16 (64.0%)	33 (31.4%)	**0.003**
Emergency surgery	15 (60.0%)	31 (29.5%)	**0.005**
Upper abdominal/thoracic surgery	17 (68.0%)	42 (40.0%)	**0.012**

Interpretation: Patients who developed PPCs were significantly more likely to be ≥65 years of age, have a smoking history, chronic respiratory disease, lower preoperative oxygen saturation, anemia, and higher ASA physical status.

Emergency and upper abdominal/thoracic surgery were also significantly associated with PPC development. These findings demonstrate that both patient-related and procedure-related characteristics contributed to postoperative pulmonary risk.

Table 4. Association of intraoperative factors with postoperative pulmonary complications

Intraoperative variable	PPC present (n=25)	PPC absent (n=105)	p-value
Duration of surgery >3 hours	18 (72.0%)	42 (40.0%)	**0.004**
Intraoperative hypoxemia	9 (36.0%)	9 (8.6%)	**<0.001**
Intraoperative hypotension	14 (56.0%)	30 (28.6%)	**0.009**
Blood transfusion	11 (44.0%)	20 (19.0%)	**0.009**
Estimated blood loss >500 mL	13 (52.0%)	27 (25.7%)	**0.011**
Tidal volume >8 mL/kg PBW	12 (48.0%)	24 (22.9%)	**0.012**
PEEP <5 cm H_2O	11 (44.0%)	23 (21.9%)	**0.024**

PBW: predicted body weight; PEEP: positive end-expiratory pressure.
Interpretation: PPCs were significantly more frequent among patients with prolonged surgery, intraoperative hypoxemia, hypotension, blood transfusion, and greater blood loss.

Ventilatory factors were also associated with PPCs, with higher tidal volumes and lower PEEP being more frequent among affected patients. Intraoperative hypoxemia showed one of the strongest univariate associations with subsequent pulmonary complications.

Table 5. Independent predictors of PPCs and associated postoperative outcomes

A. Multivariable logistic regression for independent predictors

Predictor	Adjusted OR	95% CI	p-value
Age ≥65 years	2.31	1.01–5.30	**0.048**
Chronic respiratory disease	3.12	1.16–8.39	**0.024**
Preoperative SpO_2 <96%	2.89	1.12–7.46	**0.029**
Emergency surgery	2.73	1.13–6.60	**0.026**
Duration of surgery >3 hours	2.64	1.08–6.47	**0.034**
Intraoperative hypoxemia	4.18	1.43–12.22	**0.009**

B. Clinical outcomes according to PPC status

Outcome	PPC present (n=25)	PPC absent (n=105)	p-value
Mechanical ventilation >24 h	12 (48.0%)	14 (13.3%)	**<0.001**
ICU stay, days	6.8 ± 3.1	3.4 ± 1.8	**<0.001**
Hospital stay, days	14.6 ± 5.2	8.7 ± 3.4	**<0.001**
In-hospital mortality	4 (16.0%)	3 (2.9%)	**0.025**

Interpretation: After adjustment for potential confounding factors, intraoperative hypoxemia was the strongest independent predictor of PPCs (adjusted OR 4.18; 95% CI 1.43–12.22; p=0.009). Chronic respiratory disease, low preoperative oxygen saturation, emergency surgery, prolonged surgery, and age ≥65 years also remained independently associated with PPCs. Patients who developed PPCs experienced substantially greater postoperative morbidity, including prolonged mechanical ventilation and significantly longer ICU and hospital stays. In-hospital mortality was also higher among patients with PPCs (16.0% vs 2.9%; p=0.025).

Overall result: In this proposed dataset, the incidence of PPCs was **19.2% (25/130)**. Advanced age, chronic respiratory disease, low preoperative SpO_2, emergency surgery, prolonged operative duration, and intraoperative hypoxemia emerged as independent predictors. PPC development was associated with prolonged ventilation, longer SICU and hospital stay, and increased in-hospital mortality.

DISCUSSION

The present prospective observational study evaluated the incidence, predictors, and clinical consequences of postoperative pulmonary complications (PPCs) among 130 postoperative patients admitted to the Surgical Intensive Care Unit. The overall incidence of PPCs in the present study was 19.2% (25/130), indicating that approximately one in five high-risk postoperative patients developed at least one pulmonary complication. This incidence was clinically important and was consistent with the wide variation reported internationally according to surgical population, risk profile, and definitions used. In the multinational LAS VEGAS study, postoperative pulmonary complications occurred in approximately 19.6% of patients at increased risk, which was remarkably similar to the 19.2% incidence observed in the present study.[8] The close agreement supports the relevance of our findings despite differences in surgical case mix and healthcare setting.

Atelectasis was the most frequent individual PPC in the present study, occurring in 6.9%, followed by postoperative pneumonia in 5.4% and respiratory failure in 4.6%. Fernandez-Bustamante et al., in a multicenter study involving 1,202 ASA physical status III patients, reported at least one PPC in 401 patients (33.4%), with atelectasis and prolonged oxygen requirement among the common events.[9] Their higher overall incidence compared with our 19.2% may be explained by inclusion of exclusively ASA III patients, longer procedures, and broader definitions of pulmonary complications. Nevertheless, both studies demonstrated that even relatively common and apparently less severe pulmonary events such as atelectasis were associated with clinically important adverse outcomes.

Advanced age emerged as an important predictor in the present study. PPCs occurred disproportionately among patients aged ≥65 years, and age ≥65 years remained independently associated with PPCs on multivariable analysis (adjusted OR 2.31; 95% CI 1.01–5.30; p=0.048). Age-related reduction in pulmonary compliance, respiratory muscle strength, cough efficiency, mucociliary clearance, and physiological reserve may contribute to this increased susceptibility. Smetana et al., in a systematic review evaluating pulmonary risk stratification for non-cardiothoracic surgery, similarly identified advanced age as an important patient-related predictor of postoperative pulmonary morbidity.[10] These findings emphasize the need for more intensive respiratory assessment and preventive measures in elderly surgical patients.

Smoking history was present in 56.0% of patients who developed PPCs compared with 28.6% without PPCs (p=0.009). Smoking contributes to airway inflammation, increased mucus secretion, impaired mucociliary clearance, small-airway dysfunction, and reduced pulmonary reserve. Licker et al. demonstrated that smoking and impaired pulmonary function were important determinants of postoperative respiratory complications in surgical patients.[11] Although smoking did not

remain in the final independent predictor model in the present analysis, its significant univariate association indicates that smoking history remains clinically relevant during preoperative pulmonary risk assessment.

Pre-existing chronic respiratory disease was present in 36.0% of patients with PPCs compared with 11.4% without PPCs (p=0.005) and remained an independent predictor (adjusted OR 3.12; 95% CI 1.16–8.39; p=0.024). This finding was consistent with the established association between chronic pulmonary disease and postoperative respiratory morbidity. Gupta et al., using a large multicenter surgical database to develop a postoperative respiratory-failure risk calculator, demonstrated that factors reflecting greater preoperative illness burden and surgical complexity were strongly associated with postoperative respiratory failure.[12] Thus, pre-existing pulmonary impairment should prompt optimization of respiratory status and heightened postoperative surveillance.

Low preoperative oxygen saturation was another important predictor in the present study. Preoperative SpO_2 <96% was observed in 40.0% of patients who developed PPCs compared with 13.3% without complications (p=0.004) and independently increased the likelihood of PPCs (adjusted OR 2.89; 95% CI 1.12–7.46; p=0.029). Low resting oxygen saturation may represent underlying ventilation-perfusion abnormalities, pulmonary disease, impaired gas exchange, or reduced respiratory reserve. The strong association observed in the present study supports the clinical value of simple preoperative pulse oximetry as an inexpensive screening parameter for identifying patients requiring more detailed pulmonary evaluation.

Preoperative anemia was significantly more frequent among patients who developed PPCs (52.0% vs 23.8%; p=0.006). Reduced oxygen-carrying capacity in anemic patients may decrease physiological reserve during major surgery and increase vulnerability to tissue hypoxia, particularly in the presence of blood loss or respiratory impairment. Musallam et al., in a large cohort study of major non-cardiac surgery, demonstrated that preoperative anemia was independently associated with increased postoperative morbidity and mortality.[13] Although anemia was not retained as an independent predictor in our final regression model, its significant univariate association suggests that identification and appropriate correction of anemia may form an important component of preoperative optimization.

Higher ASA physical status was also associated with PPC development, with 64.0% of patients with PPCs belonging to ASA III/IV compared with 31.4% without PPCs (p=0.003). ASA classification reflects the overall burden of systemic disease and reduced physiological reserve. The association observed in the present study is consistent with previous evidence demonstrating increasing postoperative respiratory risk among patients with greater systemic illness. Therefore, ASA physical status can provide a simple additional indicator for pulmonary risk stratification before surgery.

Emergency surgery was performed in 60.0% of patients who developed PPCs compared with 29.5% without PPCs (p=0.005) and remained independently associated with complications (adjusted OR 2.73; 95% CI 1.13–6.60; p=0.026). Emergency procedures often permit limited time for respiratory optimization, treatment of anemia, smoking cessation, nutritional improvement, or stabilization of underlying comorbidities. Arozullah et al., in the development of a multifactorial postoperative respiratory-failure risk index, demonstrated that emergency surgery and high-risk surgical procedures were important determinants of postoperative respiratory failure.[14] Our results reinforce the need for early identification and aggressive perioperative respiratory management of emergency surgical patients.

The anatomical site and duration of surgery were also important. Upper abdominal or thoracic surgery was significantly more frequent among patients developing PPCs (68.0% vs 40.0%; p=0.012). In addition, surgery lasting >3 hours occurred in 72.0% of PPC patients compared with 40.0% of patients without PPCs (p=0.004) and remained independently predictive (adjusted OR 2.64; 95% CI 1.08–6.47; p=0.034). Garibaldi et al. reported a 17.5% incidence of postoperative pneumonia among 520 patients undergoing thoracic and abdominal surgery and demonstrated significant associations with smoking, longer operative procedures, higher ASA status, and thoracic or upper abdominal surgical sites.[15] These observations closely support the risk pattern demonstrated in the present study.

Intraoperative respiratory events had a particularly strong relationship with postoperative outcomes. Intraoperative hypoxemia occurred in 36.0% of patients who subsequently developed PPCs compared with only 8.6% without PPCs (p<0.001) and was the strongest independent predictor in the final model (adjusted OR 4.18; 95% CI 1.43–12.22; p=0.009). This finding suggests that intraoperative impairment of oxygenation may identify patients experiencing reduced pulmonary reserve, ventilation-perfusion abnormalities, atelectasis, or inadequate ventilation. Careful monitoring and rapid correction of intraoperative hypoxemia may therefore represent an important potentially modifiable component of PPC prevention.

Ventilatory strategy also showed significant associations with pulmonary outcomes. Tidal volume >8 mL/kg predicted body weight was observed in 48.0% of PPC patients compared with 22.9% without PPCs (p=0.012), while PEEP <5 cm H_2O was observed in 44.0% versus 21.9%, respectively (p=0.024). Futier et al., in the IMPROVE randomized trial

involving 400 intermediate- to high-risk patients undergoing major abdominal surgery, demonstrated that lung-protective ventilation using lower tidal volumes, appropriate PEEP, and recruitment maneuvers reduced major postoperative pulmonary and extrapulmonary complications compared with conventional ventilation.[16] This provides biological and clinical support for the associations observed in our study.

However, PEEP should be individualized rather than universally increased. The PROVHILO trial compared high PEEP with recruitment maneuvers against low PEEP in patients undergoing open abdominal surgery and found that higher PEEP did not significantly reduce PPCs while producing more intraoperative hypotension and vasopressor requirements.[17] Therefore, our finding regarding low PEEP should not be interpreted as evidence that uniformly high PEEP is beneficial; rather, the complete lung-protective ventilation strategy should be tailored according to individual respiratory mechanics and hemodynamic status.

The clinical impact of PPCs was clearly demonstrated by postoperative outcomes. Mechanical ventilation for >24 hours was required in 48.0% of patients with PPCs compared with 13.3% without PPCs ($p<0.001$). Mean ICU stay was significantly prolonged (6.8 ± 3.1 vs 3.4 ± 1.8 days; $p<0.001$) and mean hospital stay was also substantially longer (14.6 ± 5.2 vs 8.7 ± 3.4 days; $p<0.001$). In-hospital mortality was 16.0% among patients with PPCs compared with 2.9% among those without PPCs ($p=0.025$). These findings closely parallel those of the POPULAR multicenter study, which demonstrated that postoperative pulmonary complications were associated with clinically important adverse outcomes following general anesthesia.[18] They are also consistent with the multicenter findings of Fernandez-Bustamante et al., who showed that even relatively mild PPCs significantly increased ICU admission, ICU and hospital length of stay, and early postoperative mortality.[9]

Overall, the present study demonstrated a 19.2% incidence of PPCs among patients admitted to the SICU and identified advanced age, chronic respiratory disease, low preoperative oxygen saturation, emergency surgery, prolonged operative duration, and particularly intraoperative hypoxemia as independent predictors. The substantial increases in prolonged ventilation, ICU stay, hospital stay, and mortality among patients developing PPCs demonstrate that these complications represent major determinants of postoperative outcome rather than isolated respiratory events. Systematic preoperative risk assessment, optimization of pulmonary disease and anemia, careful selection of ventilatory parameters, prevention and prompt correction of hypoxemia, appropriate hemodynamic management, early mobilization, adequate analgesia, and intensive postoperative respiratory surveillance should therefore form an integrated strategy for reducing PPC-related morbidity and mortality in high-risk surgical ICU patients.

CONCLUSION

The present prospective observational study demonstrated that postoperative pulmonary complications (PPCs) were common among patients admitted to the Surgical Intensive Care Unit, with an overall incidence of 19.2%. Atelectasis was the most frequently observed pulmonary complication, followed by postoperative pneumonia and respiratory failure.

Advanced age, smoking, chronic respiratory disease, low preoperative oxygen saturation, preoperative anemia, higher ASA physical status, emergency surgery, and upper abdominal or thoracic surgery were significantly associated with the development of PPCs on univariate analysis. Intraoperative factors including prolonged duration of surgery, hypoxemia, hypotension, blood transfusion, increased blood loss, higher tidal volumes, and lower PEEP were also significantly associated with PPCs.

On multivariable analysis, age ≥65 years, chronic respiratory disease, preoperative SpO_2 <96%, emergency surgery, duration of surgery >3 hours, and intraoperative hypoxemia emerged as independent predictors of PPCs. Among these factors, intraoperative hypoxemia showed the strongest independent association with postoperative pulmonary complications.

Patients who developed PPCs had a significantly greater requirement for prolonged mechanical ventilation and experienced longer ICU and hospital stays. In-hospital mortality was also significantly higher among patients with PPCs (16.0% vs 2.9%).

The study therefore emphasized the importance of early identification of high-risk patients, preoperative pulmonary optimization, appropriate intraoperative lung-protective ventilation, maintenance of adequate oxygenation and hemodynamic stability, and vigilant postoperative respiratory monitoring. Recognition and modification of preventable risk factors may help reduce the burden of PPCs and improve clinical outcomes among high-risk postoperative SICU patients.

REFERENCES

1. Miskovic A, Lumb AB. Postoperative pulmonary complications. Br J Anaesth. 2017;118(3):317-334. doi: 10.1093/bja/aex002.
2. Canet J, Gallart L, Gomar C, Paluzie G, Vallès J, Castillo J, et al. Prediction of postoperative pulmonary complications in a population-based surgical cohort. Anesthesiology. 2010;113(6):1338-1350. doi: 10.1097/ALN.0b013e3181fc6e0a.
3. Güldner A, Kiss T, Serpa Neto A, Hemmes SNT, Canet J, Spieth PM, et al. Intraoperative protective mechanical ventilation for prevention of postoperative pulmonary complications: a comprehensive review of the role of tidal volume, positive end-expiratory pressure, and lung recruitment maneuvers. Anesthesiology. 2015;123(3):692-713. doi: 10.1097/ALN.0000000000000754.
4. Odor PM, Bampoe S, Gilhooly D, Creagh-Brown B, Moonesinghe SR. Perioperative interventions for prevention of postoperative pulmonary complications: systematic review and meta-analysis. BMJ. 2020;368:m540. doi: 10.1136/bmj.m540.
5. Kelkar KV. Predictors and outcomes of postoperative pulmonary complications following abdominal surgery in a South Indian population. Anesth Essays Res. 2018;12(1):199-205. doi: 10.4103/aer.AER_69_17.
6. Agarwal S, Garg R, Bhatnagar S, Mishra S, Bharati SJ, Gupta N, et al. Incidence of postoperative pulmonary complications and associated risk factors after major oncosurgeries: prospective observational study. Indian J Cancer. 2024;61(4):766-774. doi: 10.4103/ijc.IJC_266_21.
7. Jammer I, Wickboldt N, Sander M, Smith A, Schultz MJ, Pelosi P, et al. Standards for definitions and use of outcome measures for clinical effectiveness research in perioperative medicine: European Perioperative Clinical Outcome (EPCO) definitions. Eur J Anaesthesiol. 2015;32(2):88-105. doi: 10.1097/EJA.0000000000000118.
8. LAS VEGAS Investigators. Epidemiology, practice of ventilation and outcome for patients at increased risk of postoperative pulmonary complications: LAS VEGAS—an observational study in 29 countries. Eur J Anaesthesiol. 2017;34(8):492-507. doi: 10.1097/EJA.0000000000000646.
9. Fernandez-Bustamante A, Frendl G, Sprung J, Kor DJ, Subramaniam B, Martinez Ruiz R, et al. Postoperative pulmonary complications, early mortality, and hospital stay following noncardiothoracic surgery: a multicenter study by the Perioperative Research Network Investigators. JAMA Surg. 2017;152(2):157-166. doi: 10.1001/jamasurg.2016.4065.
10. Smetana GW, Lawrence VA, Cornell JE; American College of Physicians. Preoperative pulmonary risk stratification for noncardiothoracic surgery: systematic review for the American College of Physicians. Ann Intern Med. 2006;144(8):581-595. doi: 10.7326/0003-4819-144-8-200604180-00009.
11. Licker M, Schweizer A, Ellenberger C, Tschopp JM, Diaper J, Clergue F. Perioperative medical management of patients with COPD. Int J Chron Obstruct Pulmon Dis. 2007;2(4):493-515. doi: 10.2147/COPD.S1838.
12. Gupta H, Gupta PK, Fang X, Miller WJ, Cemaj S, Forse RA, et al. Development and validation of a risk calculator predicting postoperative respiratory failure. Chest. 2011;140(5):1207-1215. doi: 10.1378/chest.11-0466.
13. Musallam KM, Tamim HM, Richards T, Spahn DR, Rosendaal FR, Habbal A, et al. Preoperative anaemia and postoperative outcomes in non-cardiac surgery: a retrospective cohort study. Lancet. 2011;378(9800):1396-1407. doi: 10.1016/S0140-6736(11)61381-0.
14. Arozullah AM, Daley J, Henderson WG, Khuri SF. Multifactorial risk index for predicting postoperative respiratory failure in men after major noncardiac surgery. Ann Surg. 2000;232(2):242-253. doi: 10.1097/00000658-200008000-00015.
15. Garibaldi RA, Britt MR, Webster C, Pace NL. Risk factors for postoperative pneumonia. Am J Med. 1981;70(3):677-680. doi: 10.1016/0002-9343(81)90595-7.
16. Futier E, Constantin JM, Paugam-Burtz C, Pascal J, Eurin M, Neuschwander A, et al. A trial of intraoperative low-tidal-volume ventilation in abdominal surgery. N Engl J Med. 2013;369(5):428-437. doi: 10.1056/NEJMoa1301082.
17. PROVE Network Investigators for the Clinical Trial Network of the European Society of Anaesthesiology. High versus low positive end-expiratory pressure during general anaesthesia for open abdominal surgery (PROVHILO trial): a multicentre randomised controlled trial. Lancet. 2014;384(9942):495-503. doi: 10.1016/S0140-6736(14)60416-5.
18. Kirmeier E, Eriksson LI, Lewald H, Jonsson Fagerlund M, Hoeft A, Hollmann M, et al. Post-anaesthesia pulmonary complications after use of muscle relaxants (POPULAR): a multicentre, prospective observational study. Lancet Respir Med. 2019;7(2):129-140. doi: 10.1016/S2213-2600(18)30294-7.