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Predictors of postoperative pulmonary complications following elective general surgery: a prospective observational cohort study.

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Abstract

Background

Postoperative pulmonary complications (PPCs) contribute substantially to morbidity, prolonged hospitalisation, and critical-care use after major surgery. Identifying readily available clinical predictors can improve perioperative risk stratification.

Objectives

To determine the cumulative incidence and pattern of PPCs and identify clinical and perioperative predictors following elective general surgery

Methods

This single-centre prospective observational cohort study included 100 adults undergoing elective general surgery at Konaseema Institute of Medical Sciences and Research Foundation, Amalapuram, India, from January to December 2025. Demographic, clinical, anaesthetic, and operative variables were recorded prospectively. Patients were followed throughout postoperative hospitalisation for new PPCs. Associated factors were examined using univariate analysis and multivariable logistic regression.

Results

Twenty-four patients developed at least one new PPC, yielding a cumulative incidence of 24.0% (24 cases per 100 patients). Univariate associations were observed for age ≥60 years (P=0.004), smoking (P=0.014), pre-existing respiratory disease (P=0.004), ASA III status (P=0.012), open surgery (P=0.010), upper abdominal surgery (P=0.006), operative duration >150 minutes (P=0.020), and postoperative nasogastric tube use (P=0.026). Independent predictors were age ≥60 years (aOR 2.84, 95% CI 1.05-7.68; P=0.039), smoking (aOR 2.67, 95% CI 1.01-7.08; P=0.048), respiratory disease (aOR 3.72, 95% CI 1.18-11.76; P=0.025), upper abdominal surgery (aOR 3.18, 95% CI 1.12-9.02; P=0.030), and operative duration >150 minutes (aOR 2.74, 95% CI 1.01-7.45; P=0.048). PPCs were associated with longer hospital stay (8.6±3.4 vs 5.1±2.0 days; P<0.001) and more ICU admissions (29.2% vs 5.3%; P=0.003).

Conclusion

PPCs affected approximately one-quarter of patients after elective general surgery. A small set of routinely identifiable clinical and operative characteristics independently predicted postoperative pulmonary morbidity.

Recommendations

Structured pulmonary risk assessment, smoking cessation, optimisation of respiratory disease, lung-protective perioperative care, early mobilisation, and enhanced surveillance should be prioritised in high-risk patients.

Keywords: *postoperative pulmonary complications; general surgery; risk factors; respiratory complications; smoking*
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Introduction: Postoperative pulmonary complications (PPCs) remain an important source of morbidity after noncardiothoracic surgery. They include clinically significant respiratory events such as atelectasis, pneumonia, bronchospasm, pleural effusion, respiratory failure, aspiration-related injury, and the need for unexpected ventilatory support. Their reported frequency varies because surgical populations, follow-up periods, and diagnostic definitions differ across studies. Nevertheless, PPCs consistently contribute to longer hospitalisation, greater use of critical care resources, higher treatment costs, and poorer postoperative outcomes [1-3]. Standardised perioperative outcome definitions have improved

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comparability across contemporary studies, although heterogeneity in surveillance and reporting persists [4,5].

The pathogenesis of PPCs is multifactorial. General anaesthesia reduces functional residual capacity, alters respiratory muscle activity, impairs mucociliary clearance, and promotes dependent atelectasis. Surgical pain, abdominal incisions, residual neuromuscular blockade, recumbency, and delayed mobilisation can further compromise ventilation and effective coughing [1]. Patient-related vulnerability also contributes substantially. Older age, cigarette smoking, chronic respiratory disease, impaired functional status, and higher American Society of Anesthesiologists (ASA) physical status have repeatedly been associated with pulmonary morbidity after surgery [2,3,6,7]. These factors are clinically useful because most can be identified before surgery and some are amenable to optimisation.

Procedure-related characteristics modify pulmonary risk independently of baseline health. Upper abdominal surgery can impair diaphragmatic excursion and produce restrictive ventilatory changes, while open procedures generally cause greater postoperative pain and mechanical respiratory limitation than minimally invasive approaches. Longer operations extend exposure to anaesthesia, mechanical ventilation, fluid shifts, and immobilisation. Large cohort studies have also linked prolonged operative duration, complex abdominal procedures, and higher perioperative risk status with PPCs [8-11]. In prospective Indian data, older age, nasogastric tube use, intraoperative pulmonary events, and higher ARISCAT risk category have been associated with postoperative respiratory complications [10]. Such findings support context-specific assessment rather than reliance on a single risk variable. Accurate identification of high-risk patients is therefore central to preventive perioperative care. Risk stratification can guide respiratory optimisation, smoking cessation, physiotherapy, lung-protective ventilation, postoperative analgesia, early ambulation, and closer surveillance. Evidence also suggests that targeted preoperative physiotherapy and breathing-exercise education can reduce PPCs after major abdominal surgery [12,13]. However, the relative contribution of clinical and operative predictors can differ among institutions because of case mix, surgical practice, perioperative protocols, and resource availability. The present study was undertaken to evaluate PPCs in adults undergoing elective general surgery at a tertiary-care teaching institution in coastal Andhra Pradesh. The primary objective was to determine the incidence and spectrum of PPCs during postoperative hospitalisation. The secondary objective was to examine demographic, clinical, anaesthetic, and operative factors associated with PPC development and to identify independent predictors using multivariable logistic regression. A further objective was to compare hospital stay and intensive care utilisation between patients with and without PPCs.

Methodology

Study design and setting

This single-centre prospective observational cohort study was conducted in the Department of General Surgery, in coordination with the Department of Anaesthesiology, at Konaseema Institute of Medical Sciences and Research Foundation, Amalapuram, Andhra Pradesh, India. This tertiary-care teaching hospital receives elective general surgical cases from Amalapuram and surrounding districts. Recruitment and follow-up were performed from January 2025 to December 2025.

Study participants

Adults aged 18 years or older scheduled for elective general surgery who provided written informed consent were screened. Emergency operations, thoracic or cardiac procedures, preoperative invasive mechanical ventilation, and incomplete essential perioperative records were exclusion criteria. Of 112 patients assessed, six failed to meet eligibility criteria, four declined participation, and two had incomplete records; 100 patients were included. Consecutive eligible patients were enrolled.

Study size

The minimum sample size was estimated using the single-proportion formula, $n = Z^2p(1-p)/d^2$. An anticipated PPC incidence of 5% was used based on a prospective Indian study [10], with $Z=1.96$ for 95% confidence and absolute precision (d) of 4.5%. Thus, $n = (1.96)^2 \times 0.05 \times 0.95/(0.045)^2 = 90.1$, giving a minimum of approximately 90 participants. Allowing about 10% for non-participation or incomplete records increased the target to approximately 99; therefore, a final target sample of 100 adults was adopted. Consecutive eligible patients were enrolled until the target was achieved.

Data collection: Demographic and clinical variables were recorded prospectively using a structured case-record form. These included age, sex, body mass index (BMI), haemoglobin, hypertension, diabetes mellitus, pre-existing respiratory disease, smoking history, and ASA physical status. Operative variables comprised open or laparoscopic approach, surgical site, anaesthetic technique, operation duration, intraoperative blood transfusion, and postoperative nasogastric tube placement. Upper abdominal procedures were analysed separately because operative site is a recognised determinant of pulmonary risk [2,3,6,7,9-11].

Outcome assessment: The primary outcome was development of at least one PPC during postoperative hospitalisation. Events were identified clinically and supported, when indicated, by

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radiography, laboratory testing, blood-gas analysis, or respiratory-support requirements. PPCs included atelectasis, pneumonia, bronchospasm, respiratory failure, pleural effusion requiring intervention, and unplanned postoperative ventilatory support. Classification was guided by European Perioperative Clinical Outcome and standardised pulmonary endpoint frameworks [4,5]. Patients with multiple respiratory events were counted once for the composite PPC outcome, while each complication was recorded separately. Hospital stay and intensive care unit admission were also documented.

Bias control

Consecutive recruitment reduced selection bias. Baseline variables were documented before postoperative outcomes wherever feasible. Uniform definitions and a standard case-record form were used for all participants to reduce information bias. Multivariable analysis was used to account for measured confounding among clinically relevant predictors.

Statistical analysis: Continuous variables were expressed as mean ± standard deviation and categorical variables as frequency and percentage. Independent-samples t tests compared continuous variables and chi-square tests assessed categorical associations. Clinically relevant or statistically significant variables from univariate analysis were entered into multivariable logistic regression. Adjusted odds ratios (aORs) with 95% confidence intervals (CIs) were reported. A two-sided P value <0.05 was considered statistically significant. Analyses used IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA).

Ethical considerations: Ethics committee approval obtained from Konaseema Institute of Medical Sciences and Research Foundation, Amalapuram, Andhra Pradesh, India before starting the study. Written informed consent was obtained from all participants, as applicable to the approved study protocol.

Results: A total of 112 patients scheduled for elective general surgery were assessed for eligibility. Twelve were excluded: six did not meet the predefined eligibility criteria, four declined participation, and two had incomplete perioperative records. Therefore, 100 patients were included in the final analysis. The mean age was 52.6 ± 13.8 years, and 58 (58.0%) participants were males. Hypertension was present in 34 (34.0%), diabetes mellitus in 26 (26.0%), pre-existing respiratory disease in 18 (18.0%), and 37 (37.0%) had a history of current or previous smoking. Most participants were classified as ASA physical status I or II (Table 1).

Table 1: Baseline demographic and clinical characteristics of the study participants (n = 100)

Variable	Value
Age, years, mean ± SD	52.6 ± 13.8
Age ≥60 years	34 (34.0%)
Male sex	58 (58.0%)
Female sex	42 (42.0%)
BMI, kg/m², mean ± SD	25.8 ± 4.1
BMI ≥30 kg/m²	18 (18.0%)
Hypertension	34 (34.0%)
Diabetes mellitus	26 (26.0%)
Pre-existing respiratory disease	18 (18.0%)
Current/former smoking	37 (37.0%)
Haemoglobin, g/dL, mean ± SD	12.8 ± 1.7
ASA physical status I	38 (38.0%)
ASA physical status II	48 (48.0%)
ASA physical status III	14 (14.0%)

Data are presented as mean ± standard deviation or n (%). BMI, body mass index; ASA, American Society of Anesthesiologists

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Regarding perioperative characteristics, 44 (44.0%) patients underwent open surgery and 56 (56.0%) underwent laparoscopic surgery. Upper abdominal procedures accounted for 39 (39.0%) operations. The mean operative duration was 126.4 ± 47.8 minutes, and surgery lasted more than 150 minutes in 31 (31.0%) patients. General anaesthesia was used in 82 (82.0%) participants. Overall, 24 patients developed at least one new PPC during postoperative hospitalisation, corresponding to a cumulative incidence of 24.0% (24 cases per 100 patients). Atelectasis was the most frequent complication, followed by pneumonia, bronchospasm, and respiratory failure (Table 2).

Table 2. Operative characteristics and postoperative pulmonary complications (n = 100)

Variable	n (%) or Mean ± SD
Operative characteristics	
Open surgery	44 (44.0%)
Laparoscopic surgery	56 (56.0%)
Upper abdominal surgery	39 (39.0%)
Lower abdominal surgery	36 (36.0%)
Other general surgical procedures	25 (25.0%)
General anaesthesia	82 (82.0%)
Combined general/regional anaesthesia	18 (18.0%)
Duration of surgery, min, mean ± SD	126.4 ± 47.8
Surgery duration >150 min	31 (31.0%)
Intraoperative blood transfusion	11 (11.0%)
Postoperative nasogastric tube	28 (28.0%)
Postoperative pulmonary complications	
Any PPC	24 (24.0%)
Atelectasis	11 (11.0%)
Pneumonia	7 (7.0%)
Bronchospasm	5 (5.0%)
Respiratory failure	4 (4.0%)
Pleural effusion requiring intervention	3 (3.0%)
Unplanned ventilatory support	4 (4.0%)

PPC,postoperative pulmonary complication. Individual pulmonary complications were not mutually exclusive because some patients experienced more than one event.

Patients who developed PPCs were more likely to be aged ≥60 years, have a smoking history, pre-existing respiratory disease, and ASA physical status III. Operative characteristics associated with PPC development included open surgery,

upper abdominal surgery, prolonged operative duration, and postoperative nasogastric tube placement. Patients with PPCs were significantly older than those without PPCs (61.3 ± 10.7 versus 49.9 ± 13.4 years; P <0.001). PPCs occurred in 41.2% of patients aged ≥60 years compared with 15.2% of younger patients. Open surgery was associated with a higher PPC incidence than laparoscopic surgery (36.4% versus 14.3%; P = 0.010) (Table 3).

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Table 3. Clinical and perioperative factors associated with postoperative pulmonary complications

Variable	PPC present (n = 24)	PPC absent (n = 76)	P value
Age ≥60 years	14 (58.3%)	20 (26.3%)	0.004
Male sex	16 (66.7%)	42 (55.3%)	0.326
BMI ≥30 kg/m²	7 (29.2%)	11 (14.5%)	0.102
Smoking history	14 (58.3%)	23 (30.3%)	0.014
Pre-existing respiratory disease	9 (37.5%)	9 (11.8%)	0.004
Hypertension	11 (45.8%)	23 (30.3%)	0.164
Diabetes mellitus	9 (37.5%)	17 (22.4%)	0.139
ASA physical status III	7 (29.2%)	7 (9.2%)	0.012
Open surgery	16 (66.7%)	28 (36.8%)	0.010
Upper abdominal surgery	15 (62.5%)	24 (31.6%)	0.006
Surgery duration >150 min	12 (50.0%)	19 (25.0%)	0.020
Intraoperative blood transfusion	5 (20.8%)	6 (7.9%)	0.075
Postoperative nasogastric tube	11 (45.8%)	17 (22.4%)	0.026

PPC, postoperative pulmonary complication; BMI, body mass index; ASA, American Society of Anesthesiologists. P <0.05 was considered statistically significant.

On multivariable logistic regression analysis, age ≥60 years, smoking history, pre-existing respiratory disease, upper abdominal surgery, and operative duration >150 minutes remained independent predictors of PPCs. Pre-existing respiratory disease showed the strongest adjusted association, with an aOR of 3.72 (95% CI 1.18-11.76; P = 0.025). Upper abdominal surgery was associated with an aOR of 3.18 (95% CI 1.12-9.02; P = 0.030). ASA physical status III and open surgical approach did not remain independently significant after adjustment (Table 4).

Table 4. Multivariable logistic regression analysis of predictors of postoperative pulmonary complications

Predictor	Adjusted OR	95% CI	P value
Age ≥60 years	2.84	1.05-7.68	0.039
Smoking history	2.67	1.01-7.08	0.048
Pre-existing respiratory disease	3.72	1.18-11.76	0.025
ASA physical status III	2.31	0.65-8.24	0.196
Upper abdominal surgery	3.18	1.12-9.02	0.030
Open surgical approach	2.26	0.82-6.22	0.115
Surgery duration >150 min	2.74	1.01-7.45	0.048

OR, odds ratio; CI, confidence interval P <0.05 was considered statistically significant.

Patients who experienced a PPC had a less favourable postoperative course. Their mean hospital stay was 8.6 ± 3.4 days, compared with 5.1 ± 2.0 days among patients without PPCs (P <0.001). Intensive care unit admission occurred in 7 (29.2%) patients with PPCs compared with 4 (5.3%) patients

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without PPCs (P = 0.003). Overall, these results indicate that pulmonary morbidity after elective general surgery was concentrated among patients with greater baseline respiratory vulnerability and higher procedural burden.

Discussion

In this prospective observational cohort of 100 adults undergoing elective general surgery, 24 patients developed at least one new PPC during postoperative hospitalisation, corresponding to a cumulative incidence of 24.0% (24 cases per 100 patients). Atelectasis was the most frequent event, followed by pneumonia, bronchospasm, and respiratory failure. This incidence is higher than that reported in some broad noncardiac surgical cohorts but is compatible with studies enriched for abdominal procedures or higher-risk patients, in whom reported PPC rates vary considerably according to case mix and outcome definitions [8-11]. The finding reinforces the clinical importance of active

postoperative respiratory surveillance rather than relying only on severe endpoints such as reintubation or prolonged ventilation.

Age ≥60 years independently increased the odds of PPCs. Age-related loss of respiratory reserve, reduced cough effectiveness, comorbidity burden, and greater susceptibility to anaesthesia-related atelectasis provide plausible mechanisms. Canet et al. incorporated advanced age into a widely used predictive model, while other abdominal-surgery studies have similarly identified older age as a significant risk factor [3,9-11]. Smoking history also remained independently associated with PPCs in the present analysis. Tobacco exposure impairs mucociliary clearance, promotes airway inflammation, and increases secretion burden; systematic and cohort evidence consistently links smoking with postoperative respiratory morbidity [6,7,9,14].

Pre-existing respiratory disease produced the strongest adjusted association in this cohort (aOR 3.72, 95% CI 1.18-11.76; P=0.025). This accords with previous work showing that chronic pulmonary disease and abnormal respiratory status increase vulnerability to postoperative hypoxaemia, infection, bronchospasm, and respiratory failure [1,3,6,7]. ASA physical status III was associated with PPCs on univariate analysis (29.2% vs 9.2%; P=0.012) but was not independently significant after adjustment (aOR 2.31, 95% CI 0.65-8.24; P=0.196), suggesting overlap with age, respiratory disease, and operative characteristics. Similar observations are plausible because ASA status is a global marker of systemic illness rather than a pulmonary-specific measure [10,11].

Upper abdominal surgery and operative duration longer than 150 minutes were independent procedural predictors. Upper abdominal incisions can reduce diaphragmatic excursion and vital capacity, while longer procedures increase exposure to mechanical ventilation, anaesthetic agents, recumbency, and fluid shifts [1,3,9,11]. Open surgery showed a higher PPC incidence on univariate analysis (36.4% vs 14.3%; P=0.010) but was not independently significant after adjustment (aOR 2.26, 95% CI 0.82-6.22; P=0.115), indicating that surgical site, duration, and patient vulnerability accounted for part of its apparent effect. Patients with PPCs also experienced substantially longer hospital stays and more ICU admissions, consistent with multicentre evidence showing that pulmonary morbidity has consequences beyond the respiratory event itself [2,8].

These results support a prevention strategy centred on early risk recognition. High-risk patients can be prioritised for smoking cessation, treatment optimisation, preoperative respiratory education, lung-protective intraoperative ventilation, adequate postoperative analgesia, mobilisation, and structured breathing exercises. Evidence from randomised trials and individual-patient meta-analysis supports preoperative physiotherapy for major abdominal surgery [12,13].

Generalizability

The findings are most applicable to adult patients undergoing elective general surgical procedures in tertiary-care teaching hospitals with a case mix comparable to the present institution. The observed predictors are clinically plausible and broadly consistent with multicentre evidence, supporting cautious transfer to similar Indian surgical settings. However, differences in surgical complexity, anaesthetic practice, pulmonary optimisation, postoperative monitoring, and institutional resources can alter both PPC incidence and predictor strength; external validation in larger multicentre cohorts is therefore appropriate.

Conclusion

Postoperative pulmonary complications occurred in 24% of adults undergoing elective general surgery in this prospective cohort and were associated with clinically important increases in hospital stay and intensive care utilisation. Advanced age, smoking history, pre-existing respiratory disease, upper abdominal surgery, and operative duration exceeding 150 minutes were independent predictors of PPCs. These variables are readily identifiable during routine perioperative assessment and can help clinicians recognise patients who require enhanced respiratory optimisation and surveillance. The findings emphasise that pulmonary risk reflects both patient vulnerability and procedural burden. Integrating structured preoperative assessment with appropriate intraoperative and postoperative preventive measures could strengthen perioperative safety and reduce respiratory morbidity after elective general surgical procedures.

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Limitations

This study has several limitations. It was conducted at a single tertiary-care centre with a relatively small sample, which limits precision of the regression estimates. Follow-up was confined to the index hospitalisation, so complications occurring after discharge were not captured. Some predictors, including detailed spirometric indices, functional capacity, and laboratory-based risk variables, were not evaluated. Residual confounding from unmeasured perioperative factors remains possible.

Recommendations

Routine preoperative assessment should include age, smoking exposure, respiratory comorbidity, ASA status, planned surgical site, and anticipated operative duration. Patients with identified risk factors should receive targeted respiratory optimisation, smoking-cessation counselling, appropriate preoperative physiotherapy or breathing-exercise education, and careful anaesthetic planning. Lung-protective ventilation, adequate analgesia, early mobilisation, selective use of nasogastric tubes, and prompt recognition of postoperative respiratory deterioration should form part of perioperative pathways. Hospitals should consider a simple PPC risk checklist for elective general surgery. Larger multicentre prospective studies should validate the predictors identified here and determine whether risk-guided interventions reduce pulmonary complications, ICU utilisation, and length of hospital stay

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Abbreviations

aOR, adjusted odds ratio; ARISCAT, Assess Respiratory Risk in Surgical Patients in Catalonia; ASA, American Society of Anesthesiologists; BMI, body mass index; CI, confidence interval; EPCO, European Perioperative Clinical Outcome; ICU, intensive care unit; PPC, postoperative pulmonary complication; SD, standard deviation.

Conflict of interest

The authors declare no conflict of interest.

Source of funding

The study received no external funding.

Data availability

The datasets generated and analysed during the current study are available from the corresponding author on reasonable request, subject to institutional ethical and confidentiality requirements.

Author Contributions

Dr. Aditya Raghav Golakoti: Conceptualization, study design, clinical supervision, patient recruitment, data interpretation, critical revision of the manuscript, and final approval of the version to be published.

Dr. Shami Un Nisa: Data collection, clinical assessment, literature review, data organization, drafting of the manuscript, and revision of the manuscript for important intellectual content.

Dr. Pidugu Bhavani: Perioperative assessment, evaluation of anaesthesia-related and postoperative pulmonary parameters, data analysis and interpretation, manuscript preparation, coordination of the study, and correspondence with the journal.

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