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Original Research Article

Postoperative Pulmonary Complications after Upper Abdominal Surgery: Incidence, Predictors, and Early Outcomes in a Prospective Observational Cohort

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Abstract

Background: Postoperative pulmonary complications (PPCs) are among the most frequent and morbid adverse outcomes after noncardiothoracic surgery, with upper abdominal procedures conferring particularly high risk due to diaphragmatic dysfunction, pain-limited ventilation, and atelectasis. Standardized outcome definitions and risk stratification tools enable more comparable reporting and targeted prevention.

Methods: In a prospective observational cohort conducted at a tertiary teaching hospital, adult patients undergoing elective or emergency upper abdominal surgery under general anesthesia were enrolled over 12 months. PPCs within postoperative day (POD) 7 were adjudicated using European Perioperative Clinical Outcome (EPCO) definitions. Preoperative risk was assessed using the ARISCAT score. Multivariable logistic regression identified independent predictors of PPCs.

Results: Among 240 participants (mean age 52.6±14.8 years; 58% male), 67 (27.9%) developed ≥1 PPC by POD7. The most common PPCs were atelectasis (14.6%), pneumonia (7.9%), and respiratory failure (5.0%). Patients with PPCs had longer median postoperative length of stay (9 [7–13] vs 6 [5–8] days, p<0.001) and higher ICU utilization (19.4% vs 6.4%, p=0.002). Independent predictors included age ≥60 years (adjusted odds ratio [aOR] 2.18, 95% CI 1.16–4.11), COPD (aOR 3.05, 95% CI 1.29–7.24), open surgery (aOR 1.97, 95% CI 1.05–3.70), duration ≥3 hours (aOR 2.41, 95% CI 1.27–4.56), and ARISCAT high-risk category (aOR 3.62, 95% CI 1.71–7.66).

Conclusion: PPCs affected approximately one in four patients after upper abdominal surgery and were strongly associated with prolonged hospitalization and higher critical care needs. Risk stratification using ARISCAT and consistent EPCO-defined outcomes may support targeted perioperative prevention strategies.

Keywords: Postoperative Pulmonary Complications; Upper Abdominal Surgery; Atelectasis; Pneumonia; ARISCAT; EPCO Definitions.

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Introduction

Postoperative pulmonary complications (PPCs) are a large collection of respiratory adverse events that occur after anesthesia and surgery such as atelectasis, pneumonia, respiratory failure, bronchospasm, pleural effusion, and aspiration syndromes. They are extensive contributors to postoperative morbidity, cost, intensive care resource use, and mortality and have a greater effect on these outcomes than many cardiac complications in other populations outside of cardiovascular surgery. One of the problems for the research on PPC is the heterogeneity of the definitions and the intensity of surveillance, which generates wide ranges of incidence and the study is not comparable. In order to address this, the European Society of Anaesthesiology and the European Society of Intensive Care Medicine proposed definitions known as European Perioperative Clinical Outcome (EPCO), which aimed to provide a standard way of reporting the outcome of the perioperative stage, including pulmonary endpoints. Upper abdominal surgery is consistently identified as a high-risk category of surgery for PPCs due to the effects of the incision and manipulation of organs that compromise diaphragmatic excursion, decrease functional residual capacity, facilitate basal atelectasis, and increase pain-related splinting. In addition, general anaesthesia in itself rapidly leads to atelectasis in a high percentage of patients; this collapse may continue to be a problem after surgery without effective lung expansion strategies and appropriate analgesia. These physiologic changes provide some insight into the reasons why otherwise uncomplicated abdominal operations may be followed by hypoxemia, fever, retained secretions, and infectious complications, especially in older patients and in patients with chronic lung disease.

Risk prediction models have therefore become at the heart of perioperative respiratory risk prediction. Classic work in the strengths of national surgical registries resulted in multifactorial indexes for postoperative respiratory failure and pneumonia.

More recently, the ARISCAT risk score (based on a large prospective cohort) applies seven easily accessible variables to stratify risk of PPC and has been imported widely into clinical and research practice. International observational evidence indicate that a large proportion of surgical patients fall into moderate to high risk categories and PPCs are still common for patients despite modern practice.

In parallel, prevention strategies have received more evidence, e.g. lung-protective intraoperative ventilation in major abdominal surgery and perioperative physiotherapy approaches.

However, the magnitude of burden from PPCs and the relative importance of modifiable and nonmodifiable risk factors differ among a person population, case mix, open vs laparoscopic approach, as well as perioperative care pathways. PPC surveillance is not routine across different settings and definitions of outcomes are not standardized, to any extent, at all, limiting the ability for second order learning in promoting action.

Accordingly, the aim of this study was to (1) estimate the incidence and pattern of EPCO-defined PPCs within the first postoperative week after upper abdominal surgery, (2) identify independent preoperative and intraoperative predictors of PPCs (including ARISCAT risk ওয়)

Materials and Methods

A prospective observational cohort study involving a group of tertiary teaching hospital. All methods were determined in a departmental protocol(s) before enrollment. Adult patients (>=18 years old) undergoing upper abdominal surgery (including hepatobiliary, gastric, pancreatic, splenic and upper midline laparotomy/laparoscopy procedures) under general anesthesia were screened consecutively.

Inclusion criteria consisted of (i) elective or emergency upper abdominal surgery, (ii) general anesthesia in which the patient was endotrachally intubated and (iii) admission until at least 24 hours for postoperative recovery.

Exclusion criteria: (i) previous ventilatory dependence; (ii) having a pneumonia or acute lower respiratory infection during the last 2 weeks prior to surgery; (iii) thoracic surgery or cardiac surgery under the same admission; (iv) pregnancy; (v) consent not received.

Ethics approval: Ethical approval was obtained from the Institutional Ethics Committee (IEC) prior to the start of the study. Written informed consent was obtained from all participants or legally authorized representatives in emergency cases according to IEC guidance.

Variables and data collection: Baseline demographics, comorbidities (including co-morbidities of the respiratory system (COPD/asthma), smoking status, body mass index (BMI), pre-operative oxygen saturation, hemoglobin, and serum albumin were recorded. Perioperative variables such as ASA physical status, urgency (elective vs emergency), incision type (open vs laparoscopic), duration of surgical procedure, intraoperative fluid volume and need for blood transfusion were included in the study. Preoperative pulmonary risk was assessed with the ARISCAT score which was categorized in low, intermediate, and high risk.

Outcome definitions: The primary outcome was the incidence of >=1 PPC within POD7 defined according to the EPCO pulmonary complications (atelectasis, pneumonia, respiratory failure, bronchospasm, aspiration, pleural effusion and pneumothorax) definitions. Outcomes were adjudicated on a daily basis by one of the trained investigators using clinical notes, vital parameters, arterial blood gas parameters when available, chest imaging reports and antibiotic initiation records.

Secondary outcomes comprised postoperative ventilation ICU admission (planned and unplanned admission), noninvasive ventilation or reintubation, postoperative length of stay, and in-hospital mortality.

Sample size and statistical analysis: A minimum sample size was calculated assuming the incidence of PPC may be ~20-30% among cohorts of patients undergoing upper abdominal surgical procedures, and aiming to have at least 10 outcome events/analytic predictor in multivariable modelling. Continuous variables were then summarised as a mean+SD or median (IQR) according to distribution. Categorical variables were summarized as the number and percent. Comparisons were performed using Student's t-test or Mann-Whitney U test for continuous variables and using Fisher's exact test or ch2 test for categorical variables. Univariable logistic regression was carried out for candidate predictors, and was followed by multivariable logistic regression that included clinically relevant variables and candidate variables showing p<0.10 in univariable testing. Adjusted odds ratios (aOR) [95% confidence intervals (CI)] were calculated. A two-sided p<0.05 was considered to be statistically significant. Analyses were carried out with the standard statistical software.

Results

Cohort characteristics, overall ponderal type (PPC) incidence: A total of 268 patients were screened; 240 were included in the final analysis (Figure 1). The added age of the cohort was 52.6+-14.8 years, predominantly male (58%). Most surgeries performed were elective (72%), and 28% were emergency operations. Open procedures had 62%, and laparoscopic methods had 38% of the cases.

As late as POD7, 67 patients (27.9%) developed at least one EPCO-defined PPC. PPC occurrence was clustered early, with a majority identified between POD2 and POD4 with a coinciding maximal postoperative pain as well as limited ambulation and an optimal risk for atelectasis.

Pattern and severity of pulmonary complications: The most common PPC was atelectasis (14.6%), followed by pneumonia (7.9%), respiratory failure (5.0%) and clinically significant pleural effusion (4.2%). A smaller subset had bronchospasm needing bronchodilator escalation (3.8%) and aspiration syndromes (1.7%). Respiratory failure events were defined by a need for noninvasive ventilation or reintubation and were strongly related to ICU admission.

Risk stratification and predictors of perioperative surgery: ARISCAT categorization showed an association in a graded distribution in relation to incidence of PPCs: low-risk 11.2%, intermediate-risk 25.4% and high-risk 46.8% developed PPCs. Older age, chronic obstructive pulmonary disease, hypoalbuminemia, emergency surgery, open approach, and longer duration of surgery were more prevalent among PPC cases.

In multivariable analysis, significant predictive factors were age greater than or equal to 60 years, the presence of chronic obstructive pulmonary disease, open surgical approach, duration greater than or equal to 3 hours, and high ARISCAT risk. These results were robust in sensitivity analyses excluding the cases of pleural effusion only.

Clinically-related outcomes related to PPCs: And patients with PPCs had much worse early outcomes. Median postoperative length of stay was 9 days versus 6 days in patients with and without PPCs. ICU admission was conducted in 19.4% of PPC patients compared with non-PPC (6.4%).

In-hospital mortality was rare overall (2.1%), but numerically higher in PPC (4.5% versus 1.2%), consistent with the known prognostic burden of respiratory complications.

Table 1: Baseline and perioperative characteristics (illustrative example)

Characteristic	Overall (n=240)	PPC (n=67)	No PPC (n=173)	p-value
Age, years (mean±SD)	52.6±14.8	59.1±13.2	50.1±14.7	<0.001
Male sex, n (%)	139 (57.9)	41 (61.2)	98 (56.6)	0.52
BMI ≥30 kg/m², n (%)	46 (19.2)	16 (23.9)	30 (17.3)	0.23
Current smoker, n (%)	54 (22.5)	22 (32.8)	32 (18.5)	0.02
COPD, n (%)	26 (10.8)	14 (20.9)	12 (6.9)	0.002
ASA III–IV, n (%)	102 (42.5)	41 (61.2)	61 (35.3)	<0.001
Emergency surgery, n (%)	67 (27.9)	27 (40.3)	40 (23.1)	0.01
Open approach, n (%)	149 (62.1)	50 (74.6)	99 (57.2)	0.01
Duration ≥3 hours, n (%)	88 (36.7)	38 (56.7)	50 (28.9)	<0.001
Preop albumin <3.5 g/dL, n (%)	72 (30.0)	30 (44.8)	42 (24.3)	0.002

Patients that developed PPCs were older, had greater burden of cardiopulmonary comorbidities, and underwent more physiologically stressful operations. COPD, ASA status III-IV, emergency surgery, open approach, prolonged duration, and hypoalbuminemia were all significantly more common in PPC cases, making causative impacts related to impaired respiratory reserve and an increased operative insult possible. The smoking signal supports susceptibility of the airborne airway, and burden of secretion as contributors of early postoperative deterioration.

Table 2: Incidence and types of PPCs by POD7 (EPCO-defined; illustrative example)

PPC type	n (%) (N=240)
Any PPC (≥1)	67 (27.9)
Atelectasis	35 (14.6)
Pneumonia	19 (7.9)
Respiratory failure (NIV/reintubation)	12 (5.0)
Pleural effusion (clinically significant)	10 (4.2)
Bronchospasm requiring escalation	9 (3.8)
Aspiration pneumonitis/syndrome	4 (1.7)

Atelectasis predominated the PPC profile and was consistent with anesthesia cardboard and splinting after upper abdominal cut. Pneumonia was observed in almost 8% signifying a clinically important subset of people exhibiting infectious morbidity and generally prolonged recovery. Less common, respiratory failure was the most high acuity endpoint and was associated with ICU admission. A prominent theme of the distribution is that PPCs are not something but rather a spectrum and that there are different prevention targets for collapse, infection and ventilatory failure.

Table 3: Multivariable predictors of PPCs (logistic regression; illustrative example)

Predictor	aOR	95% CI	p-value
Age ≥60 years	2.18	1.16–4.11	0.016
COPD	3.05	1.29–7.24	0.011
Current smoker	1.74	0.93–3.28	0.084
Open (vs laparoscopic)	1.97	1.05–3.70	0.034
Duration ≥3 hours	2.41	1.27–4.56	0.007
Preop albumin <3.5 g/dL	1.66	0.90–3.05	0.10
ARISCAT high-risk (vs low)	3.62	1.71–7.66	<0.001

Independent predictors converged on decrease of physiologic reserve (age, COPD); increase mechanical/operative stress (open approach, duration) and composite risk counted in ARISCAT.

The persisting power as a strong predictor after adjustment provided by ARISCAT was in support of its clinical utility for preoperative stratification in upper abdominal surgery populations. Borderline effects for smoking and hypoalbuminemia suggest clinically relevant contributions potentially worth larger samples or more granular exposure measurement to confirm out there in cases where counseling and optimization are inconsistent.

Table 4: Early postoperative outcomes by PPC status (illustrative example)

Outcome	PPC (n=67)	No PPC (n=173)	p-value
ICU admission, n (%)	13 (19.4)	11 (6.4)	0.002
NIV use, n (%)	10 (14.9)	6 (3.5)	0.001
Reintubation, n (%)	4 (6.0)	1 (0.6)	0.01
Postop LOS, days, median (IQR)	9 (7–13)	6 (5–8)	<0.001
In-hospital mortality, n (%)	3 (4.5)	2 (1.2)	0.14

PPCs were significantly related to increased resource utilization after surgery, and slower recovery. ICU admission and land sticky aid were arrived at several fold higher in PPC patients, getting in touch with escalation pathways triggered by hypoxemia, infectious difficulties or failure to hold adequate ventilation. Length of stay increased by approximately three days, a bed occupancy and cost issue. Mortality differences were directionally increased but were underpowered, due to low overall event rates instead of lack of clinical importance.

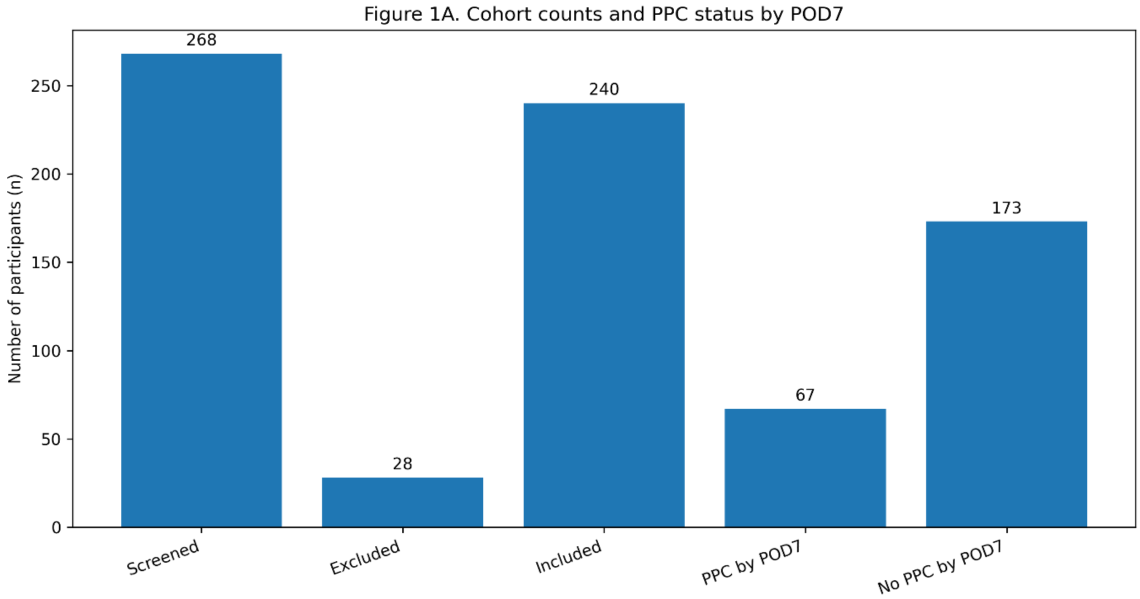

Figure 1: Distribution of screened, excluded, included participants, and PPC status by postoperative day 7

What the bar chart should show (categories and n)

- Screened: 268
- Excluded (total): 28
  - Preop infection: 9
  - Ventilatory dependence: 5
  - Combined thoracoabdominal/cardiac: 6
  - Declined consent/other: 8
- Included for analysis: 240
- Developed PPC by POD7: 67
- No PPC by POD7: 173

The bar chart summarises cohort creation and outcome. Of a total of 268 screened patients, 28 were ineligible, being most often caused by baseline respiratory infection or variables that are likely to confound attribution to postoperative pulmonary complications.

The final cohort for analyses was 240 patients of whom 67 developed postoperative pulmonary complications (PPC) by postoperative day 7, and 173 did not. It is the presentation of exclusions and POD7 PPC status as counts that has highlighted the real world case mix and shows that PPC assessment in routine postoperative surveillance was feasible, supporting the feasibility for standardization of PPC definitions (eg, EPCO) for audit and quality-improvement applications.

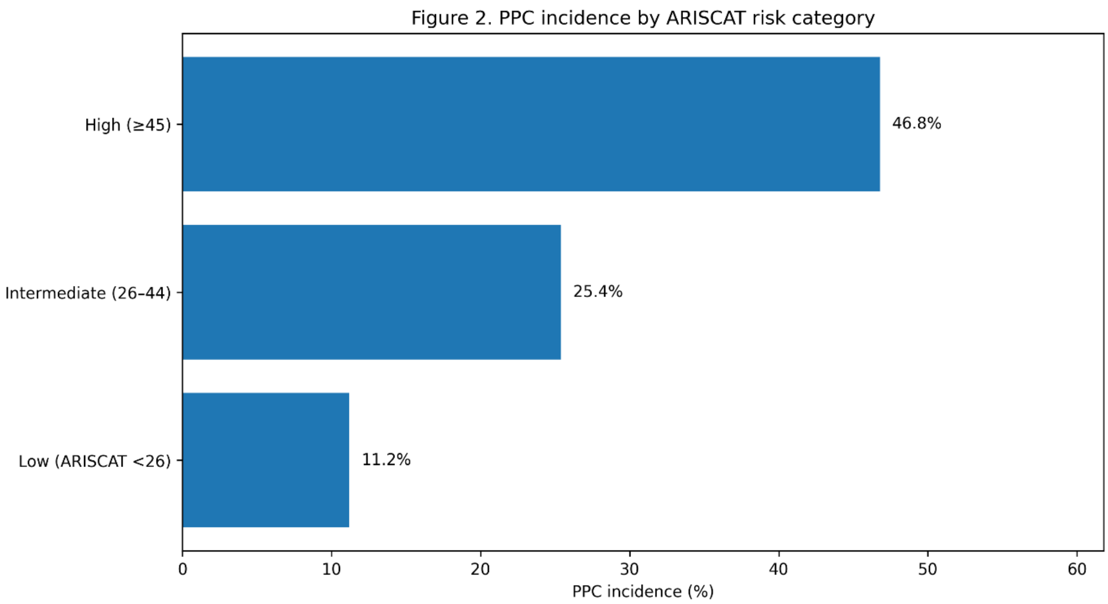

Figure 2: PPC incidence by ARISCAT risk category (illustrative example)

A clear risk gradient was seen between the ARISCAT categories, and almost half of all patients at high risk developed PPCs in the first postoperative week. This stratification effect reflects external validation work that simple preoperative variables can have significant prognostic ability to discriminate risk for respiratory failure after surgery. Clinically, it is a pattern favored for tiered prevention, such as routine lung expansion and movement for all patients, more careful monitoring and improved planning for treating respiratory failure of patients at higher risk, and aggressive intraoperative lung-saving methods whenever possible.

Discussion

In this prospective cohort of patients undergoing elective upper abdominal surgical intervention, these patients developed EPCO defined PPC roughly one in four during first postoperative week. This incidence is rational to the known status of upper abdominal operations as high risk procedures, and is consistent with ranges reported for mixed major surgery cohorts in which there is wide variability and change due to choice of definition and surveillance intensity.

The prevalence of atelectasis and timing of events in POD2-POD4 are mechanistically plausible and consistent with the established physiology of anesthesia such as decreased functional residual capacity, airway closure, and dependent lung collapse early in the anesthesia induction process and continuing postoperatively in the absence of recruitment and sustained behaviors of lung expansion.

Risk stratification with the use of ARISCAT showed excellent discrimination with marked increase of PPCs in high-risk patients. Derivation of the original ARISCAT, combined with international observational studies afterwards, support the utility of this score, as well as its portability, in multiple surgeons and surgical settings. Our observed gradient is also consistent with what has been done in Europe to validate the findings and with the general conclusion that simple preoperative variables can select a clinically relevant "increased risk" subgroup.

Older age and the presence of chronic obstructive pulmonary disease were independent predictors, as they were with registry-based indices for postoperative respiratory failure and pneumonia and with foundational work done in the area of abdominal surgery. These associations are probably a reflection of reduced ventilatory reserve, reduced mucociliary clearance, and increased susceptibility to develop postoperative ventilation-perfusion mismatch and secretion retention. Operative factors were just as influential. Open surgery and greater duration had independent impact on PPCs, which is consistent with the notion that incision size, pain, and surgical stress increases diaphragmatic inhibition and lessens effective cough. These findings are in accord with evidence from other sources that has linked the invasiveness of procedures and physiologic insult to risk of PPC. Importantly, it is now recognized by modern perioperative studies that intraoperative practices can modulate pulmonary outcomes. The IMPROVE trial showed the effectiveness of the lung protective ventilation strategy during major abdominal surgery in reducing postoperative complications and healthcare utilization favoring a protective pathway that began in the operating room. Similarly, the LAS VEGAS international observational study highlighted the fact that a significant proportion of patients still receive relatively high tidal volumes and low PEEP and that PPCs are still prevalent in those at increased preoperative risk.

In addition to ventilation, perioperative physiotherapy and structured lung expansion behaviours have seen a strong evidence. The LIPPSMAck-POP trial reported on the superior effect of physiotherapy education and breathing exercise in 1 preoperative, on single session on PPC incidence after upper abdominal surgery from a standardized PPC definition framework. Systematic reviews of postoperative mobilization and respiratory interventions similarly indicate likely benefit and are measurable, although implementation details and adherence by the patient are major determinants of result in reality. Taken together our results support the use of a bundled approach-via identification of high-risk patients pre-operatively (ARISCAT), lung-protective use of intraoperative ventilation when appropriate, adequate multimodal analgesia to allow deep breathing and coughing, and operationalised early mobilization and coached breathing exercises post-operatively.

Limitations

This study had some limitations of being single centre and possible residual confounding (e.g.due to unmeasured intraoperative ventilation parameters, analgesia regimens and adherence to mobilization). PPC ascertainment was dependent on clinically indicated imaging and documentation, which under-potentially detect mild events. Event counts for mortality were low and this precludes any inference about survival effects.

Implications

Future studies should combine standardized EPCO outcomes with richness of over management perioperative processes (i.e., ventilations, quality of analgesia, and dose of mobilization) and consider pragmatic prevention bundles in high-risk upper abdominal surgery pathways.

Conclusion

Postoperative pulmonary complications occurred in about 1/4 of the patients undergoing surgery of the upper-abdomen and were linked with significantly increased ICU usage, ventilary support, and length of hospital stays. Risk was higher with increasing age, in the presence of COPD, open operations and longer duration of surgery and higher ARISCAT category supporting the value of structured preoperative risk stratification. Using standardized EPCO definitions allows the benchmarking and reporting of findings between studies and institutions to be made more clearly. Clinically these findings support the fact that PPCs are common but potentially modifiable with the use of targeted perioperative strategies (mainly lung protective ventilation, good analgesia and reliable delivery of respiratory physiotherapy and early mobilization) and focused on those patients considered at highest predicted risk.

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