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Original Article

Pulmonary complications following urological, gastrointestinal and gynaecological abdominal Surgery––A post-hoc analysis of an observational study in 29 countries

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A B S T R A C T

Background: The incidence of postoperative pulmonary complications (PPCs[3]) following abdominal surgery varies across surgical specialties. It remains unclear to what extent the incidence of PPCs is attributable to known patient–related factors and anaesthesia duration, rather than to differences inherent to the surgical specialty itself.
Methods: Post-hoc analysis of an observational study describing postoperative outcomes in patients undergoing urological, gastrointestinal, and gynaecological abdominal surgery. The primary endpoint was a composite measure of PPCs. Secondary endpoints included the individual incidence of each PPC. Propensity score weighting was used to create a cohort with similar patient characteristics and anaesthesia duration.
Results: The cohort consisted of 3306 patients across 146 centres in 29 countries–367 underwent urological surgery, 2100 underwent gastrointestinal surgery, and 839 underwent gynaecological surgery. Risk scores for PPCs were highest in urological surgical patients, followed by gastrointestinal and gynaecological surgical patients. PPCs also occurred most often after urological surgery (17.7%), followed by gastrointestinal (14.9%) and gynaecological surgery (9.8%) ($p < 0.001$). After weighting, these differences in incidence disappeared, with comparable rates across the three groups (urological surgery 15.7%, gastrointestinal 14.5%, gynaecological 12.2%; $p = 0.340$). Apart from unplanned supplementary oxygen, all PPCs were most frequent after gastrointestinal surgery and least common following gynaecological surgery.
Conclusions: In this worldwide cohort of patients undergoing abdominal surgery, the incidence of PPCs varied across urological, gastrointestinal, and gynaecological surgery; the differences in incidence may be more strongly influenced by patient–related factors and anaesthesia duration than by the characteristics of the surgical specialty itself. Gastrointestinal surgeries showed the highest rates of severe PPCs.

1. Introduction

Postoperative pulmonary complications (PPCs), even when mild, are associated with prolonged hospital stay, increased mortality, and greater healthcare burden [1–5]. Abdominal surgery is a well-recognised risk factor for PPCs [3,6,7], but its incidence varies across different surgical specialties [2]. Patient-related factors, such as age and comorbidities, and duration of anaesthesia are also well-established risk factors for PPCs [6], and these vary across surgical populations [8]. However, the specialty of the surgical procedure itself may also contribute, as urological, gastrointestinal, and gynaecological surgeries involve different organs and anatomic regions with varying proximity to the lungs. It remains unclear to what extent the variation in PPC incidence is attributable to patient characteristics and anaesthesia duration, rather than to differences inherent to the surgical specialty.

PPCs are often assessed using composite measures that group several types of pulmonary complications into a single outcome. However, such composite measures may obscure important differences in the incidence, severity, and causal relationships of individual PPCs. It is therefore important to consider individual pulmonary complications in addition to the overall composite incidence. A more detailed understanding of which patients and procedures carry the greatest risk for specific PPCs could help identify modifiable risk factors, support the targeted use of perioperative lung–protective strategies, and enhance the prevention, early recognition, and management of these complications [9].

We re-analysed the database of the 'Local Assessment of Ventilatory management during General Anaesthesia for Surgery' (LAS VEGAS) study [10]. We hypothesised that the incidence of PPCs after urological, gastrointestinal, and gynaecological surgery is more driven by patient characteristics and anaesthesia duration than by differences inherent to the surgical specialty itself. A propensity score weighted analysis was performed to create groups with comparable patient characteristics and duration of anaesthesia. In addition, we ranked and compared the severity of individual PPCs across the three surgical groups.

[3] Postoperative Pulmonary Complications.

2. Methods

2.1. Study design

Post hoc analysis of LAS VEGAS [10], a worldwide, prospective, one–week observational study describing intraoperative ventilation management and postoperative complications in the first five postoperative days in patients undergoing surgery in 146 centres across 29 countries. Patients were enrolled between 14 January and 4 March 2013. The study protocol of LAS VEGAS was first approved on 22 August 2012 by the ethics committee of the Academic Medical Centre, Amsterdam, The Netherlands (W12_190#12.17.0227, chairperson Prof. M.P.M. Burger). If needed, approval was obtained from the institutional review board in other centres, and depending on national or regional legislation, written informed consent was obtained from each individual patient. The study was conducted according to the guidelines of the Declaration of Helsinki. LAS VEGAS was registered at clinicaltrials.gov (study identifier NCT01601223). The statistical analysis plan for the current analysis was predefined and approved by the LAS VEGAS steering committee before data extraction. This report followed the guidelines and recommendations of the 'STrengthening the Reporting of OBservational studies in Epidemiology' (STROBE) statement (Supplementary Table 1) [11].

2.2. Inclusion and exclusion criteria

The LAS VEGAS study included consecutive patients who received invasive ventilation during general anaesthesia for all types of surgery during a predefined calendar week in 2013. Exclusion criteria of LAS VEGAS were: (1) age < 18 years, (2) obstetric surgery, (3) surgery with cardiopulmonary bypass, and (4) surgery that was not performed in the operating room.

For this analysis, we excluded patients who had received invasive ventilation before surgery, patients who underwent one–lung intraoperative ventilation, and patients with missing data for PPCs. Next, we excluded patients undergoing procedures that were not classified as urological, gastrointestinal, or gynaecological surgery. In LAS VEGAS, urological, gastrointestinal, and gynaecological surgery comprised both abdominal and non–abdominal procedures. Surgeries which were classified as non–abdominal, such as hysteroscopy or cystoscopy, were excluded. At last, patients who were classified for multiple surgical specialties, such as a combination of gastrointestinal and urological surgery, were excluded from analysis.

2.3. Data recording and processing

The following data were collected in LAS VEGAS: (1) baseline characteristics and demographic data, including but not limited to sex at birth, age, body weight and height, functional status, comorbidities, anaesthesia and surgical characteristics and risk for PPCs by means of the 'Assess Respiratory Risk in Surgical Patients in Catalonia' (ARISCAT) risk score [6]; (2) intraoperative ventilation parameters, (3) occurrence of predefined PPCs in the first five postoperative days and (4) date of hospital discharge and life–status at hospital discharge or day 28.

2.4. Endpoints

The primary endpoint was a composite measure of PPCs in the first five postoperative days. The composite measure included six different PPCs, as defined below in Section 2.5. The occurrence of one PPC was defined as having met the primary endpoint. Secondary endpoints were individual PPC incidence, length of hospital stay, and hospital mortality.

2.5. Definitions

PPCs included 1) unplanned supplementary oxygen (oxygen administered due to $PaO_2 < 8$ kPa or $SpO_2 < 90\%$ in room air, but excluding oxygen supplementation given as standard care, *e.g.*, directly after arrival in the postanaesthesia care unit); 2) pneumothorax (air in the pleural space with no vascular bed surrounding the visceral pleura on the chest radiograph); 3) pneumonia (presence of a new or progressive radiographic infiltrate and at least two of three clinical features; fever > 38 °C or > 100.4 °F, leucocytosis or leukopenia (white blood cell count >12,000 cells μl^{-3} or <4000 cells μl^{-3} and purulent secretions); 4) respiratory failure ($PaO_2 < 8$ kPa or $SpO_2 < 90\%$ despite oxygen therapy, or a need for noninvasive ventilation; 5) unplanned new or prolonged invasive mechanical ventilation (after discharge from the operating room); and 6) Acute Respiratory Distress Syndrome (ARDS), defined according to the Berlin definition of ARDS [12]. Severe PPCs were classified as pneumothorax, pneumonia, respiratory failure, new invasive ventilation, and ARDS.

2.6. Sample size and statistical power

A sample size calculation was not performed. Instead, all patients who underwent abdominal surgery within the LAS VEGAS cohort served as the sample for this investigation. A post-hoc power analysis was performed using G*power (v3.1.9.7, Universität Kiel, 2020) [13] and tested the null hypothesis of equal PPC incidence across all surgical groups. Using a Chi–square test and based on statistical conventions [14,15], we defined a small effect size of surgical specialty ($w \leq 0.100$) as clinically relevant. With a sample size of 3306, two degrees of freedom, and an alpha of 0.05, our study had 90% power to detect an effect size of w = 0.062. In the propensity score weighted cohort, we had 90% power to detect an effect size of w = 0.068.

2.7. Statistical analysis

Continuous variables are presented as medians with interquartile range; categorical variables are expressed in numbers and percentages. Descriptive statistics were used to visualise patient demographics and intraoperative characteristics. Categorical variables were compared between three groups with a chi–square test. Continuous variables were compared between three groups using a one–way ANOVA test or Kruskal-Wallis test where appropriate. Differences at baseline between the three groups were expressed in p-values and standardised mean differences (SMD) for each possible group pair.

The composite incidence of PPCs was compared between three groups with a chi-square test. Individual PPC incidence between groups was compared with a chi-square test and visualised in a bar chart. Individual PPCs were ranked on increasing severity in the following order: unplanned supplementary oxygen; pneumothorax; pneumonia; respiratory failure; new invasive ventilation and ARDS. If a patient suffered multiple PPCs, only the most severe PPC was counted for this endpoint. Length of hospital stay was compared with a one–way ANOVA test. Mortality was assessed with a chi-square test. 28-day survival between groups is presented as a Kaplan-Meijer curve.

Subsequently, propensity score weighting was performed. Each patient was assigned a weight based on 1) duration of anaesthesia and 2) patient characteristics with clinical relevance – *i.e.*, with a known association with development of PPCs – including age; preoperative SpO_2, preoperative anaemia; respiratory infection in the preceding month; emergency surgery; functional status; and presence of one or more chronic comorbidities. Duration of anaesthesia and patient characteristics were quantified as a propensity score by means of logistic regression. For each patient, the propensity score was converted to a weight. Missing data (Supplementary Table 2) were imputed using multiple imputation (five computations, five iterations and pooled results, MICE package) if data were considered missing completely at random. Balance of covariates after weighting was visualised in a LOVEplot. Adequate balance was defined as not exceeding 0.2 SMD. From all three possible group pairs, the group pairing with the highest SMD was used for each variable to construct the LOVEplot.

After weighting, the same analyses were repeated for all endpoints. We performed several sensitivity analyses using different weighting models to evaluate the findings for the primary endpoint. Three post-hoc analyses were conducted to 1) evaluate severe PPCs across the three groups and 2) to examine the association of PPCs with length of stay and mortality and 3) the association of severe PPCs with length of stay and mortality.

All analyses were performed using R statistical software (v4.3.2, R Core team, 2024). A p–value < 0.05 was considered statistically significant.

3. Results

LAS VEGAS enrolled a total of 10,520 patients. We excluded 7214 patients, primarily because these patients did not undergo abdominal surgery. Of the remaining 3306 patients, 367 patients underwent urological surgery, 2100 gastrointestinal surgery, and 839 gynaecological surgery (Fig. 1). Male sex was most common in urological surgery and absent in gynaecological surgery (Table 1). Patients who underwent urological surgery were older, had higher ARISCAT risk scores, more comorbidities, and longer durations of anaesthesia. Patients who underwent gastrointestinal surgery had poorer functional status and were more likely to undergo emergency surgery than those in the other groups. Patients who underwent gynaecological surgery were the youngest, had the lowest ARISCAT risk scores, the fewest comorbidities, and the shortest duration of anaesthesia.

3.1. Postoperative pulmonary complications

The rate of PPCs differed between groups ($p < 0.001$), occurring most frequently after urological surgery (17.7%), followed by gastrointestinal (14.9%) and gynaecological surgery (9.8%) (Table 2). Unplanned supplementary oxygen was the most common PPC across all three groups. Severe PPCs occurred most frequently following gastrointestinal surgery and least after gynaecological surgery (Table 2, Supplementary Table 3, Fig. 2). Pneumonia, pneumothorax, and ARDS occurred only after gastrointestinal surgery. The incidence of PPCs was higher after open abdominal surgery compared to minimally invasive procedures (Supplementary Tables 4 & 5).

3.2. Weighted analysis

Propensity score weighting resulted in a cohort of patients with a total of 9697 weights. Of these, 3125 weights corresponded to urological surgery, 3323 weights to gastrointestinal surgery, and 3249 weights to gynaecological surgery. Duration of anaesthesia and patient characteristics associated with PPCs were well balanced across the three groups (Table 3 and Supplementary Fig. 1). The incidence of PPCs was not different ($p = 0.340$) between urological (15.7%), gastrointestinal (14.5%), and gynaecological surgery (12.2%) (Table 2 and Fig. 3).

The results of sensitivity analyses using different weighting methods confirmed the findings of the main analysis (Supplementary Table 6). Severe PPCs and individual PPCs remained different across groups, with most PPCs occurring after gastrointestinal surgery (Table 2, Supplementary Table 3).

3.3. Length of hospital stay and mortality

Length of hospital stay was longer after urological surgery (Table 2). Mortality was higher after gastrointestinal surgery

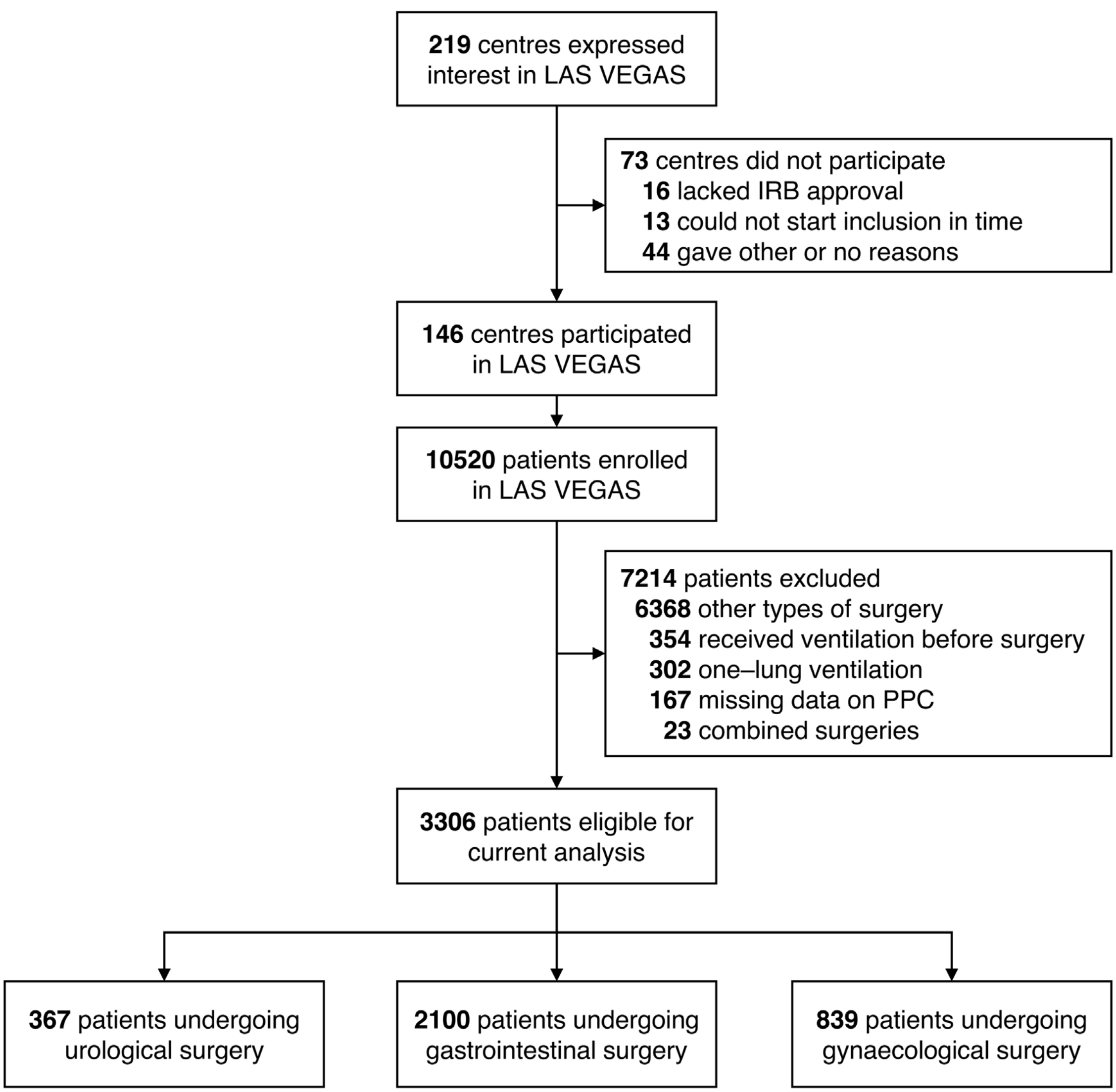

Fig. 1. CONSORT flowchart.

Table 1
Patient demographics and surgical characteristics. Values are median [IQR] or number (%).

	Urological surgery N = 367	Gastrointestinal surgery N = 2100	Gynaecological surgery N = 839	SMD I vs. II	SMD I vs. III	SMD II vs. III	3 group difference p
Demographics							
Male sex, yes	288 (78.5)	992 (47.2)	0 (0.0)	0.683	2.700	1.338	<0.001
Age, years	63 [51–70]	57 [43–69]	45 [36–55]	0.247	0.921	0.596	<0.001
BMI, kg/m^2	27 [24–30]	27 [23–31]	26 [23–30]	0.044	0.152	0.164	0.001
ARISCAT risk score	34 [31–41]	26 [18–39]	18 [15–32]	0.539	1.097	0.379	<0.001
ARISCAT risk score group				0.826	1.072	0.340	<0.001
Low, <26	51 (14.2)	987 (48.4)	476 (59.6)				
Intermediate, 26–44	260 (72.6)	784 (38.5)	287 (36.0)				
High, ≥ 45	47 (13.1)	268 (13.1)	35 (4.4)				
Functional status				0.205	0.202	0.222	<0.001
Independent	346 (94.3)	1909 (90.9)	807 (96.3)				
Partially dependent	21 (5.7)	151 (7.2)	23 (2.7)				
Totally dependent	0 (0.0)	39 (1.9)	8 (1.0)				
Preoperative[a]							
Respiratory infection, yes	15 (4.1)	92 (4.4)	29 (3.5)	0.015	0.033	0.048	0.549
Anemia, yes	14 (4.1)	126 (6.6)	39 (5.4)	0.114	0.062	0.052	0.139
SpO_2, %	97 [96–99]	98 [96–99]	98 [97–99]	0.001	0.378	0.295	<0.001
Smoker, yes	79 (21.5)	449 (21.4)	150 (17.9)	0.003	0.092	0.089	0.088
Comorbidities, yes							
One or more comorbidities	135 (36.8)	568 (27.0)	88 (10.5)	0.210	0.651	0.434	<0.001
COPD	26 (7.1)	160 (7.6)	23 (2.7)	0.020	0.202	0.221	<0.001
Heart failure	36 (9.8)	159 (7.6)	18 (2.1)	0.080	0.328	0.254	<0.001
Metastatic cancer	18 (4.9)	178 (8.5)	34 (4.1)	0.143	0.041	0.183	<0.001
Chronic kidney dysfunction	62 (16.9)	55 (2.6)	2 (0.2)	0.496	0.623	0.202	<0.001
Obstructive sleep apnoea	9 (2.5)	53 (2.5)	7 (0.8)	0.005	0.128	0.132	0.006
Liver dysfunction	2 (0.5)	32 (1.5)	2 (0.2)	0.097	0.049	0.138	0.003
Neuromuscular disease	4 (1.1)	13 (0.6)	5 (0.6)	0.051	0.054	0.003	0.549
Emergency surgery, yes	2 (0.5)	130 (6.2)	14 (1.7)	0.496	0.108	0.439	<0.001
Surgical approach, yes				0.240	0.361	0.118	<0.001
Open abdominal	220 (59.9)	1009 (48.0)	354 (42.2)				
Minimally invasive	147 (40.1)	1091 (52.0)	485 (57.8)				
Duration of anaesthesia, minutes	195 [130–254]	110 [75–182]	105 [75–160]	0.616	0.887	0.194	<0.001
In categories:				0.791	0.953	0.185	<0.001
<90 min	37 (10.2)	733 (35.2)	297 (35.5)				
90–180 min	114 (31.4)	810 (38.9)	382 (45.7)				
>180 min	212 (58.4)	541 (26.0)	157 (18.8)				
Ventilation characteristics							
Driving pressure, cm H_2O	13 [11–16]	13 [10–16]	14 [11–17]	0.177	0.012	0.197	<0.001

Data presented as median with interquartile range (25th to 75th quartile) or numbers and percentages (%(n/total)).
Group I = urological surgery; group II = gastrointestinal surgery; group III = gynaecological surgery.
Abbreviations: SMD = standardised mean difference; IQR = interquartile range; BMI = body mass index; ARISCAT = Assess Respiratory Risk in Surgical Patients in Catalonia; SpO_2 = peripheral capillary oxygen saturation; COPD = chronic obstructive pulmonary disease.
p value corresponding to test for difference between three groups.
[a] Preoperative measurements within the last month before surgery.

Table 2
Postoperative pulmonary complications, length of hospital stay and mortality in the unweighted and weighted cohort. Values are median [IQR] or number (%).

	Unweighted				Weighted			
	Urological surgery N = 367	Gastrointestinal surgery N = 2100	Gynaecological surgery N = 839	p	Urological surgery Sum of weights = 3125	Gastrointestinal surgery Sum of weights = 3323	Gynaecological surgery Sum of weights = 3249	p
Any PPC, yes	65 (17.7)	313 (14.9)	82 (9.8)	<0.001	492 (15.7)	483 (14.5)	398 (12.2)	0.340
Individual PPCs[a], yes				<0.001				0.046
No PPC	302 (82.3)	1783 (84.9)	756 (90.1)		2633 (84.3)	2833 (85.2)	2848 (87.6)	
Unplanned supplementary oxygen	55 (15.0)	196 (9.3)	74 (8.8)		374 (12.0)	303 (9.1)	369 (11.3)	
Pneumothorax	0 (0.0)	3 (0.1)	0 (0.0)		0 (0.0)	6 (0.2)	0 (0.0)	
Pneumonia	0 (0.0)	14 (0.7)	0 (0.0)		0 (0.0)	21 (0.6)	0 (0.0)	
Respiratory failure	7(1.9)	48 (2.3)	7 (0.8)		51 (1.6)	76 (2.3)	23 (0.7)	
New invasive ventilation	3 (0.8)	50 (2.4)	2 (0.2)		67 (2.2)	78 (2.4)	9 (0.3)	
ARDS	0 (0.0)	6 (0.3)	0 (0.0)		0 (0.0)	8 (0.2)	0 (0.0)	
Length of hospital stay, days	4 [1–7]	2 [1–5]	2 [0–4]	<0.001	4 [1–7]	2 [1–5]	2 [0–5]	0.015
Mortality, yes	1 (0.3)	31 (1.6)	0 (0.0)	<0.001	10 (0.3)	43 (1.4)	0 (0.0)	0.022

Data presented as median with interquartile range (25th to 75th quartile) or numbers and proportions (%(n/total)). Weights and proportions of PPCs and mortality is reported in numbers and percentages alongside weighted medians for length of hospital stay.
Abbreviations: PPC = Postoperative pulmonary complication; ARDS = Acute respiratory distress syndrome; IQR = Inter quartile range.
[a] If one patient had multiple PPCs, only the most severe PPC was counted. Severity scale: 1 = unplanned supplementary oxygen; 2 = pneumothorax; 3 = pneumonia; 4 = respiratory failure; 5 = new invasive ventilation; 6 = ARDS.

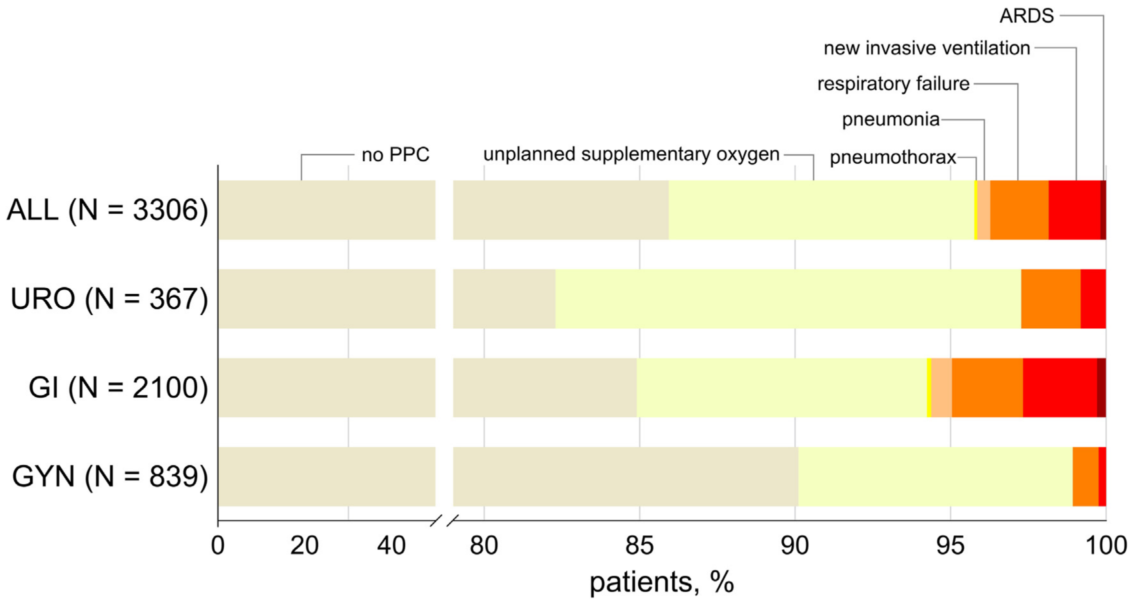

Fig. 2. Unweighted cohort. PPCs in total cohort and in the three surgical subgroups. PPCs were ranked according to severity in the following ascending order 1) unplanned supplementary oxygen; 2) pneumothorax; 3) pneumonia; 4) respiratory failure; 5) new invasive ventilation and 6) Acute Respiratory Distress Syndrome (ARDS). If a patient had multiple PPCs, only the most severe PPC was counted. Each bar represents a proportion (%). N = amount of patients. ALL = total cohort of abdominal surgical patients; URO = urological abdominal surgery; GI = gastrointestinal abdominal surgery; GYN = gynaecological abdominal surgery.

(Table 2, Supplementary Fig. 2). These findings also remained unchanged after weighting. PPCs and severe PPCs were associated with longer length of hospital stay and higher mortality in all surgery types (Supplementary Tables 7 & 8), both in the weighted and unweighted cohort.

4. Discussion

The main findings of this post-hoc analysis of LAS VEGAS are as follows: (1) patients undergoing urological surgery had the highest risk for PPCs, followed by those undergoing gastrointestinal and gynaecological procedures; (2) the rate of PPCs was also higher in urological surgery patients compared to gastrointestinal and gynaecological surgery patients; (3) after correcting for patient characteristics associated to PPCs and duration of anaesthesia, the rate of PPCs was similar between groups and (4) gastrointestinal surgery patients developed severe PPCs more often than patients in the other groups.

The overall rate of PPCs in our study was high and aligns with previous observational reports in abdominal surgery [2,6,16]. Although comparing studies that investigate PPCs can be challenging due to varying populations and differences in the PPC composites, we can relate to the secondary endpoint findings of an observational study from Italy investigating the same three surgical groups [2]. While we observed the highest rate of PPCs in urological surgery, that study reported a higher incidence in gastrointestinal surgery. This difference may be explained by variations in patient characteristics and duration of anaesthesia between the two studies. Most notably, patients undergoing abdominal surgery in the Italian study also had the highest ARISCAT risk score for PPCs, whereas gastrointestinal surgery patients in our cohort had lower ARISCAT scores and shorter duration of anaesthesia. In both studies, gynaecological surgery patients had the lowest risk and incidence of PPCs.

Other studies have reported more detailed incidences of PPCs in specific surgical groups, offering a more granular understanding of their occurrence. In gynaecological surgery, the rate of PPCs ranges from 2% in non-malignant procedures to as high as 27% in cancer-related surgery [17–20]. Cancer-related urological surgery has been associated with PPC rates ranging from 27% to 47% [21,22]. The higher incidences in patients undergoing cancer surgery seem to be related to the presence of more risk factors for PPCs, including older age and comorbidities, and prolonged duration of anaesthesia. In our weighted cohort, the incidence of PPCs became similar between groups, supporting the notion that patient characteristics and anaesthesia duration are the key determinants of PPC risk, and not the characteristics of the surgical specialty itself.

The three groups differed in the incidence of individual PPCs, with patients undergoing gastrointestinal surgery experiencing a higher rate of severe PPCs. This finding may be partly explained by the higher incidence of other postoperative complications after gastrointestinal surgery [23], which can predispose patients to PPCs [24]. In the other groups, PPCs were more often limited to the need for postoperative oxygen therapy. Notably, this difference persisted after weighting and may also explain the higher mortality observed in the gastrointestinal surgery group. Furthermore, gastrointestinal surgery patients underwent emergency procedures more often, which is a known risk factor for severe PPCs [25,26]. Clinicians caring for these patients should remain particularly vigilant, as timely recognition and management of these PPCs are critical in this high-risk population.

The findings of this analysis have direct clinical relevance, demonstrating that patient-specific risk factors and anaesthesia duration, rather than the surgical specialty itself, are the primary determinants of PPC risk. This underscores the importance of a comprehensive preoperative risk assessment and optimisation of modifiable factors regardless of surgical specialty. Such factors include correcting anaemia, delaying the intervention, the use of minimally invasive approaches, applying strict intraoperative lung–protective measures, and minimising anaesthesia duration wherever possible [6,27]. Future trials can use our detailed results for improved sample size calculations.

As highlighted by recent Delphi initiatives [28–30], reducing postoperative complications – including PPCs – continues to be a fundamental aim of modern anaesthetic care. For future PPC research, the development of a standardised and widely accepted composite definition of PPCs is essential [31]. Such harmonization

Table 3
Patient demographics and surgical characteristics after weighting. Values are median [IQR] or number (%).

	Urological surgery Sum of weights = 3125	Gastrointestinal surgery Sum of weights = 3323	Gynaecological surgery Sum of weights = 3249	SMD I *vs.* II	SMD I *vs.* III	SMD II *vs.* III	3 group difference *p*
Demographics							
Male sex, yes	2370 (75.8)	1549 (46.6)	0 (0.0)	0.629	2.506	1.322	<0.001
Age, years	60 [44 – 69]	55 [40 – 67]	51 [41 – 65]	0.122	0.174	0.046	0.066
BMI, kg/m^2	27 [24–30]	27 [23–30]	27 [23–32]	0.110	0.085	0.032	0.852
ARISCAT risk score	34 [18 – 41]	23 [15 – 38]	26 [15 – 34]	0.315	0.368	0.034	<0.001
ARISCAT risk score group				0.506	0.466	0.069	<0.001
Low, < 26	804 (27.5)	1632 (50.6)	1540 (49.4)				
Intermediate, 26–44	1767 (60.5)	1221 (37.8)	1266 (40.6)				
High, ≥ 45	351 (12.0)	375 (11.6)	311 (10.0)				
Functional status				0.178	0.173	0.032	0.131
Independent	2895 (92.6)	3080 (92.7)	3036 (93.4)				
Partially dependent	230 (7.4)	196 (5.9)	175 (5.4)				
Totally dependent	0 (0.0)	47 (1.4)	38 (1.2)				
Preoperative[a]							
Respiratory infection, yes	106 (3.4)	135 (4.0)	120 (3.7)	0.035	0.018	0.018	0.842
Anemia, yes	233 (7.4)	179 (5.4)	156 (4.8)	0.083	0.111	0.028	0.317
SpO_2, %	98 [96–99]	98 [96–99]	98 [96–99]	0.001	0.026	0.023	0.707
Smoker, yes	738 (23.6)	733 (22.1)	487 (15.0)	0.037	0.220	0.183	0.010
Comorbidities, yes							
One or more Comorbidities	891 (28.5)	790 (23.8)	805 (24.8)	0.108	0.085	0.023	0.283
COPD	167 (5.3)	218 (6.6)	172 (5.3)	0.052	0.001	0.054	0.619
Heart failure	238 (7.6)	212 (6.4)	182 (5.6)	0.049	0.082	0.033	0.474
Metastatic cancer	92 (2.9)	255 (7.7)	375 (11.5)	0.213	0.337	0.131	<0.001
Chronic kidney dysfunction	464 (14.8)	75 (2.3)	17 (0.5)	0.462	0.558	0.148	<0.001
Obstructive sleep apnoea	37 (1.2)	76 (2.3)	51 (1.6)	0.084	0.033	0.052	0.310
Liver dysfunction	6 (0.2)	45 (1.3)	11 (0.3)	0.133	0.028	0.111	0.005
Neuromuscular disease	20 (0.6)	19 (0.6)	24 (0.7)	0.010	0.013	0.022	0.889
Emergency surgery, yes	74 (2.4)	146 (4.4)	117 (3.6)	0.382	0.086	0.406	0.540
Surgical approach, yes				0.113	0.086	0.028	0.250
Open abdominal	1640 (52.5)	1556 (46.8)	1566 (48.2)				
Minimally invasive	1485 (47.5)	1767 (53.2)	1683 (51.8)				
Duration of anaesthesia, minutes	130 [80–194]	115 [78–187]	118 [80–185]	0.022	0.085	0.058	0.632
In categories:				0.040	0.025	0.015	0.958
<90 min	959 (30.7)	1077 (32.4)	1031 (31.7)				
90–180 min	1270 (40.6)	1336 (40.2)	1315 (40.5)				
>180 min	896 (28.7)	910 (27.4)	904 (27.8)				
Ventilation characteristics							
Driving pressure, cm H_2O	13 [10–16]	13 [10–16]	14 [11–17]	0.094	0.147	0.270	<0.001

Data presented as weighted median with interquartile range (25th to 75th quartile) or weighted numbers and percentages (%(n/total)).
Group I = urological surgery; group II = gastrointestinal surgery; group III = gynaecological surgery.
Abbreviations: SMD = standardised mean difference; IQR = interquartile range; BMI = body mass index; ARISCAT = Assess Respiratory Risk in Surgical Patients in Catalonia; SpO_2 = peripheral capillary oxygen saturation; COPD = chronic obstructive pulmonary disease.
p value corresponding to test for difference between three groups.
[a] Preoperative measurements within the last month before surgery.

would allow for meaningful comparison across trials and strengthen the methodological quality of meta-analyses. Furthermore, it would support more reliable identification of PPC risk factors, possibly by artificial-intelligence-based approaches [32]. This could, in turn, improve PPC outcomes by optimizing modifiable risk factors and enabling the prevention, early recognition, and management of PPCs.

This analysis has limitations. We could only assess PPCs that were collected as part of the original LAS VEGAS study [10]. There, only PPCs that could be captured as part of standard care were collected, limiting the generalisability of our findings to PPCs we did not include. Although a Delphi initiative is underway to establish a widely accepted composite of PPCs [31], a universally used and accepted composite remains lacking for now. The most recent consensus paper suggests the inclusion of a factor of severity in PPC reporting [33], which we did by showing individual PPCs incidences. Our findings only apply to patients undergoing abdominal surgery, and not to patients who underwent surgery with a non–abdominal incision. LAS VEGAS originated in 2013, and surgical as well as anaesthesia practices may have since evolved, including increased use of minimally invasive techniques and intraoperative lung–protection. Non–captured factors, such as anaesthesia technique, postoperative pain control, and the use of robotic surgical approaches, may have influenced our results, and residual confounding could have remained. As with any observational study, causality cannot be established. Additionally, propensity score weighting carries the risk of masking true differences between groups. Therefore, our findings should be viewed as hypothesis-generating, rather than replacing evidence from randomised clinical trials.

Our analysis has several strengths. It used the robust LAS VEGAS database, an international, multicentre study conducted across diverse geo-economic regions, including both academic and non-academic hospitals, as well as teaching and non-teaching centres, thereby enhancing the generalisability of our findings. Its large sample size enabled sophisticated analyses and allowed for precise estimation and control for confounding factors, as shown by the post-hoc power calculation. The result for the primary endpoint in the weighted analysis was confirmed by sensitivity analyses using different weighting methods, further supporting the robustness of our findings. We applied the same criteria for PPCs as used in the original study, thereby maintaining methodological consistency

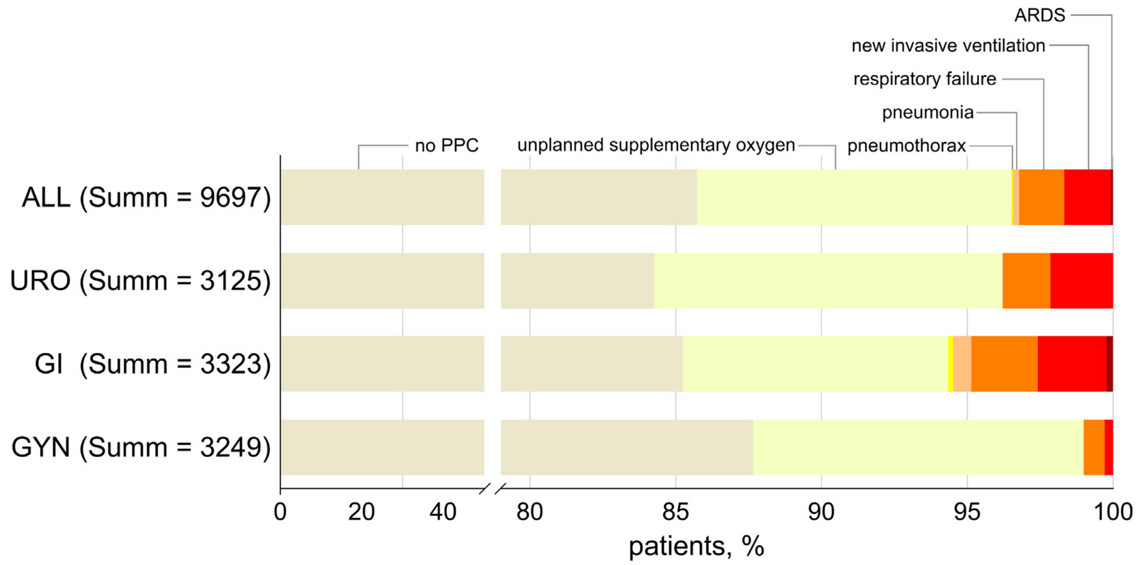

Fig. 3. Weighted cohort. PPCs in the total cohort and in the three surgical subgroups. PPCs were ranked according to severity in the following ascending order 1) unplanned supplementary oxygen; 2) pneumothorax; 3) pneumonia; 4) respiratory failure; 5) new invasive ventilation and 6) Acute Respiratory Distress Syndrome (ARDS). If a patient had multiple PPCs, only the most severe PPC was counted. Each bar represents a proportion (%). N = amount of patients. ALL = total cohort of abdominal surgical patients; URO = urological abdominal surgery; GI = gastrointestinal abdominal surgery; GYN = gynaecological abdominal surgery.

and facilitating direct comparison with previously reported findings. Additionally, the statistical analysis plan was predefined and strictly adhered to, minimising the risk of bias.

5. Conclusion

In this worldwide cohort of patients undergoing abdominal surgery, the rate of PPCs varied among patients undergoing urological, gastrointestinal, and gynaecological surgery. These variations may be driven more by patient characteristics and the duration of anaesthesia than by differences inherent to the surgical specialty itself. Gastrointestinal surgeries were associated with the highest rates of severe PPCs.

CRediT authorship contribution statement

All authors attest that they meet the current International Committee of Medical Journal Editors (ICMJE) criteria for Authorship.

Human and animal rights

The authors declare that the work described has been carried out in accordance with the Declaration of Helsinki of the World Medical Association revised in 2013 for experiments involving humans as well as in accordance with the EU Directive 2010/63/EU for animal experiments.

Informed consent and patient details

The authors declare that this report does not contain any personal information that could lead to the identification of the patient(s).

The authors declare that they obtained a written informed consent from the patients and/or volunteers included in the article. The authors also confirm that the personal details of the patients and/or volunteers have been removed.

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Declaration of competing interest

The authors declare that they have no known competing financial or personal relationships that could be viewed as influencing the work reported in this paper.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.accpm.2025.101738.

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