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Original Contribution

Association of preoperative smoking with the occurrence of postoperative pulmonary complications: A post hoc analysis of an observational study in 29 countries

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HIGHLIGHTS

- Smoking is not associated with overall postoperative pulmonary complications in at-risk patients.
- Respiratory failure was more common in smokers than non–smokers.
- Length of hospital stay and mortality were similair between smokers and non-smokers.
- Propensity score matching did not change the findings.

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ABSTRACT

Introduction: While smoking has been consistently identified as a significant contributor to postoperative complications, the existing literature on its association with postoperative pulmonary complications remains conflicting.
Aim: We examined the association of preoperative smoking with the occurrence of postoperative pulmonary complications (PPCs).
Methods: Post hoc analysis of an observational study in 146 hospitals across 29 countries. We included patients at increased risk of PPCs, according to the Assess Respiratory Risk in Surgical Patients in Catalonia (ARISCAT) score ($\geq$ 26 points). The primary endpoint was the occurrence of one or more predefined PPCs in the first five postoperative days, including unplanned postoperative need for supplementary oxygen, respiratory failure, unplanned need for invasive ventilation, ARDS, pneumonia and pneumothorax. Secondary endpoints included length of hospital stay and in–hospital mortality. We performed propensity score matching to correct for factors with a known association with postoperative outcomes.
Results: Out of 2632 patients, 531 (20.2 %) patients were smokers and 2102 (79.8 %) non-smokers. At five days after surgery, 101 (19.0 %) smokers versus 404 (19.2) non–smokers had developed one or more PPCs ($P = 0.95$). Respiratory failure was more common in smokers (5.1 %) than non–smokers (3.0 %) ($P = 0.02$), while rates of other PPCs like need for supplementary oxygen, invasive ventilation, ARDS, pneumonia, or pneumothorax did not differ between the groups. Length of hospital stay and mortality was not different between groups. Propensity score matching did not change the findings.
Conclusion: The occurrence of PPCs in smokers is not different from non–smokers.
Funding: This analysis was performed without additional funding. LAS VEGAS was partially funded and endorsed by the European Society of Anaesthesiology through their Clinical Trial Network and the Amsterdam University Medical Centers, Amsterdam, The Netherlands.
Registration: LAS VEGAS was registered at Clinicaltrials.gov (NCT01601223).
Prior presentation: Preliminary study results have been presented at the Euroanaesthesia 2024 International Congress, in Munich, Germany.

1. Introduction

Smoking is considered a risk factor in surgical patients, and contributor to the development of postoperative complications. Indeed, surgical site infection and other postoperative complications have been reported to occur more often in smokers, and to be associated with increased general morbidity, longer duration of hospital stay, and more intensive care unit admissions [1]. However, the literature is conflicting with regard to the association of preoperative smoking with postoperative pulmonary complications (PPCs). While some studies have indicated smokers to be at a higher risk of developing PPCs compared to non–smokers [2,3], others found no association of smoking with the occurrence of PPCs [4,5], and one study suggested that the effect may depend on the specific surgical procedure [6]. Consequently, the impact of preoperative smoking on PPCs remains unclear.

PPCs present significant challenges in surgical care, leading to increased morbidity, mortality and healthcare costs [7,8]. In recent years, perioperative practices have advanced significantly, raising the question of whether smoking still has a notable impact on PPCs under current practices. In patients at increased risk of PPCs, the presence of other comorbidities and risk factors may also influence outcomes, potentially moderating the effect of smoking.

Therefore, the aim of this analysis was to assess the association of preoperative smoking with the occurrence of PPCs in patients. Herein we focused on patients at an increased (i.e. intermediate or high) risk for PPCs. We tested the hypothesis, that preoperative smoking has no associations with the occurrence of PPCs, using the dataset of the conveniently sized worldwide prospective observational 'Local ASsessment of VEntilatory management during General Anesthesia for Surgery' (LAS VEGAS) study [9].

2. Methods

2.1. Study design

This is a post hoc analysis of LAS VEGAS, a worldwide, multicentre, prospective observational study, describing the incidence of patients with increased risk of PPCs, intraoperative ventilation practice and associations between ventilatory parameters and postoperative outcomes. The LAS VEGAS study protocol was first approved by the institutional

review board of the Academic Medical Center, Amsterdam, The Netherlands (W12_190#12.17.0227), and thereafter by the institutional review boards of each participating centre. If required, written informed consent from the patient or their legal representative was obtained. The study was registered at clinicaltrials.gov (NCT01601223). We report in compliance with the current guidelines and the recommendations of STrengthening the Reporting of Observational studies in Epidemiology (STROBE) statement (available at: www.strobe-statemenent.org) (Supplementary Table S1).

2.2. Patients

LAS VEGAS enrolled patients in 146 hospitals across 29 countries over a consecutive period of seven days in 2013. National coordinators selected the exact period during which data were collected for the study in their respective countries. Consecutive patients receiving invasive ventilation, via endotracheal tube or supraglottic device during general anaesthesia for elective and non–elective surgical procedures were eligible. Patients under the age of 18, those scheduled for pregnancy–related surgeries, procedures conducted outside the operating room or interventions involving cardiopulmonary bypass were excluded from LAS VEGAS.

For this current analysis, we limited inclusion to patients at increased (i.e. intermediate or high) risk of PPCs with an 'Assess Respiratory Risk in Surgical Patients in Catalonia' (ARISCAT) score above 26 points (**Supplementary Table S2)** [4]. We also applied additional exclusion criteria, as follows. We excluded patients that had received mechanical ventilation in the 30 days prior to surgery, undergoing thoracic surgery or one–lung ventilation, as well as patients with incomplete data on the preoperative smoking status, patients with missing ARISCAT scores, and patients with missing data for the primary endpoint.

2.3. Data collected

From the LAS VEGAS database the following variables were used: baseline characteristics including sex, age, body weight and height, ARISCAT score, American Society of Anesthesiologists (ASA) score, smoking status, functional status, coexisting comorbidities such as heart failure, chronic obstructive pulmonary disease, obstructive sleep apnoea syndrome (OSAS), active cancer, chronic kidney failure, liver cirrhosis, neuromuscular disease; risk factors for developing PPCs including preoperative saturation of peripheral oxygen (SpO_2), respiratory infection within the past month, preoperative anemia, type of surgical incision and emergency procedure. In LAS VEGAS, ventilation data were collected hourly after induction of anaesthesia and start of invasive ventilation until tracheal extubation, including tidal volume (V_T), positive end–expiratory pressure (PEEP), plateau (Pplat), peak airway pressure (Ppeak), fraction of inspired oxygen (FiO_2) and respiratory rate (RR).

2.4. Patient classification

Preoperative smoking was categorized into smokers and non–smokers. In LAS VEGAS, the smoking status was obtained from the preoperative patient records.

2.5. Endpoints

The primary endpoint of this analysis was occurrence of PPCs in the first five postoperative days, defined as a composite binary endpoint comprising six individual PPCs. Patients who develop at least one PPC were considered as meeting the primary endpoint. In the primary endpoint, PPCs weighted equally. Secondary endpoints included the occurrence of the individual PPCs, length of hospital stay, and in–hospital mortality.

2.6. Definitions

The composite binary endpoint of PPCs comprised the following previously described conditions: 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 post anaesthetic care unit), respiratory failure (PaO2 < 8 kPa or SpO2 < 90 % despite oxygen therapy, or a need for non-invasive positive pressure ventilation (NIPPV); unplanned new or prolonged invasive mechanical ventilation (after discharge from the operating room); acute respiratory distress syndrome (ARDS) according to the Berlin criteria [10]; pneumonia (using clinical and laboratory data) and pneumothorax (observed in the chest radiograph). Secondary endpoints comprised of the individual PPCs, categorized based on their severity, wherein unplanned supplemental oxygen was classified as 'mild' and the PPCs as 'severe' [11].

2.7. Calculations

V_T was expressed in ml per kg predicted body weight (PBW). PBW was calculated by the following formulas: in females, $45.5 + (0.91 \times (\text{height [cm]} - 152.4))$ and in males, $50 + (0.91 \times (\text{height [cm]} - 152.4))$. Driving pressure ($\Delta P$) was calculated by $\Delta P = Pplat - PEEP$ (in volume–controlled ventilation) or $\Delta P = Pmax - PEEP$ (in pressure–controlled ventilation).

2.8. Sample size

No formal sample size calculation was conducted for this analysis; instead, the number of eligible patients in the LAS VEGAS database determined the sample size. A post hoc power calculation was performed for the primary endpoint.

2.9. Statistical analysis

Patients were stratified into two groups based on their preoperative smoking status. Demographic, baseline characteristics and outcome variables are presented as medians and interquartile ranges in case of continuous variables and categorical variables are presented as numbers and percentages. Groups were compared using the Mann–Whitney *U* test for continuous variables and the Fisher exact or Chi-square tests for categorical variables. No assumptions for missing data were made. Length of hospital stay and in–hospital death was censored at postoperative day 28.

The incidence of total, mild or severe PPCs in smokers and non–smokers was compared using Fisher's exact test.

As one sensitivity analysis, we performed a propensity score matching to control for potentially confounding factors that could have affected outcomes. Patients were matched according to age, ARISCAT score and functional status using a one–to–one nearest neighbour algorithm without replacement. Variables included in the propensity score model were selected based on clinical relevance and baseline imbalance, as indicated by standardized mean differences (SMDs). Variables with an SMD ≥ 0.1 were initially considered, with final selection based on clinical relevance i.e. with a known association with PPCs. Variables standardized mean differences were visualized in a LOVE plot and used to assess matching performance. No correction for multiple testing was performed as this analysis was considered to be exploratory.

All analyses were performed in R version 4.2.1 (Core Team, Vienna, Austria, 2021). A *P* value less than 0.05 was considered statistically significant.

3. Results

3.1. Patients

Out of 9864 patients present in the LAS VEGAS database, 2803 (28.4 %) patients were at an increased risk of PPCs as defined by an ARISCAT score ≥ 26 points (Fig. 1). A total of 171 patients were excluded for other reasons as mentioned in the flow chart. Out of the remaining 2632 patients, 531 (20.2 %) patients were smokers and 2102 (79.8 %) were non-smokers. Compared to non–smokers, smokers were generally younger, predominantly male, more often at intermediate risk for PPCs according to the ARISCAT score, had a lower BMI, a higher incidence of respiratory infections within 30 days before surgery, were more frequently independent functional state, and had higher rates of chronic obstructive pulmonary disease (COPD) and liver cirrhosis but a lower incidence of heart failure (Table 1). Smokers more often underwent vascular and aortic surgeries, while gynecologically and transplant surgeries were less common among them, with intraoperative characteristics being comparable between smokers and non-smokers (Table 2).

3.2. Occurrence of PPCs

The overall incidence of PPCs did not differ between smokers and non–smokers. At 5 days after surgery, 101 (19.0 %) smokers versus 404 of 2101 non–smokers (19.2 %) had developed one or more PPCs (P = 0.95) (Fig. 2, Table 3). Respiratory failure was more common in smokers (5.1 %) than non–smokers (3.0 %) (P = 0.02), while rates of other PPCs such as need for supplementary oxygen, invasive ventilation, ARDS, pneumonia, or pneumothorax did not differ between the groups.

3.3. Length of hospital stay and in–hospital mortality

Length of hospital stay and in–hospital mortality were not different between smokers and non–smokers (Table 3).

3.4. Post hoc power and sensitivity analysis

Propensity score matching did not change the findings (Tables 1, 2, 3 **and** Fig. 3). Considering that the total PPC incidence in smokers is 20 % and in non-smokers 10.4 % [9,12,13], with an unmatched cohort sample size of 2632 patients, with an α of 0.05, and a smoker to non-smoker ratio of 0.25, the post hoc power analysis showed that we had 99 % power to detect this difference.

4. Discussion

The main findings of this post hoc analysis in a prospective cohort of patients receiving intraoperative ventilation during general anaesthesia for surgery and at increased (i.e. intermediate or high) risk for PPCs can be summarized as follows: [1] the overall occurrence of PPCs did not

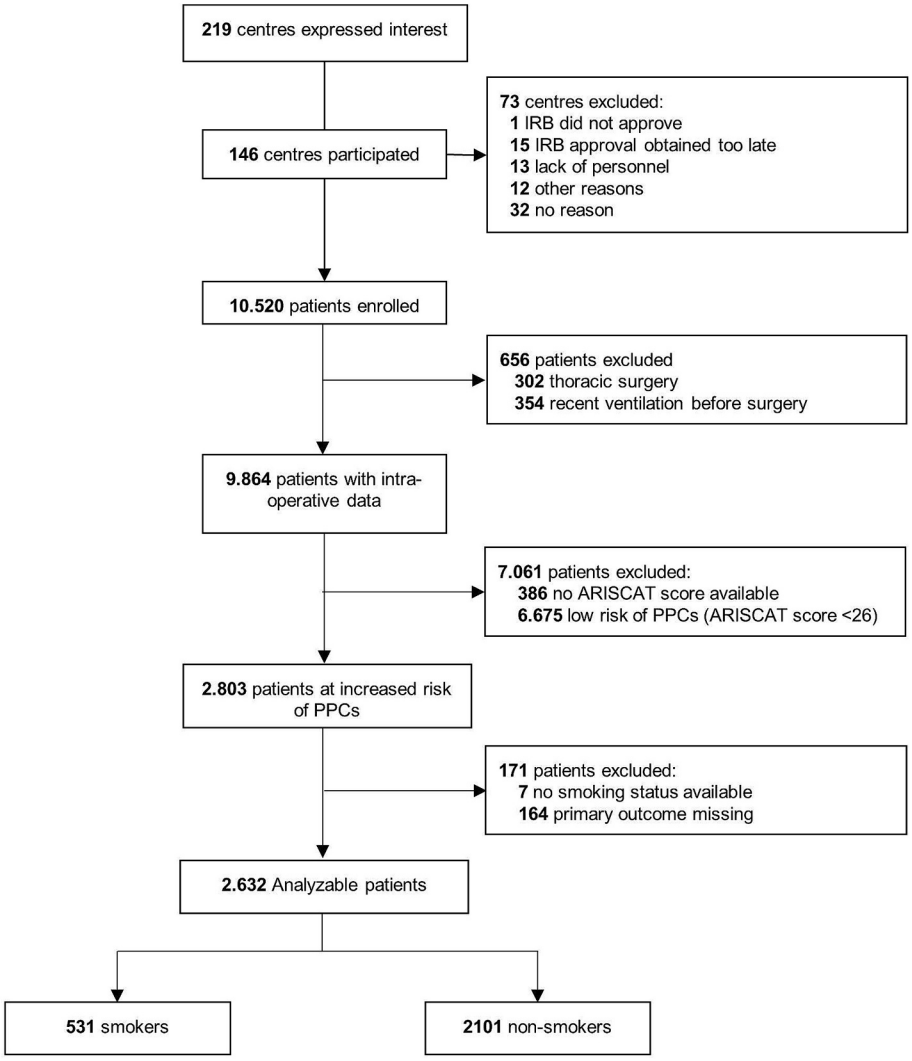

Fig. 1. CONSORT flowchart.

Table 1
Patient characteristics unmatched and matched cohorts.

	Unmatched cohort			Matched cohort		
	Smoker $N = 531$	Non-smoker $N = 2101$	SMD	Smoker $N = 520$	Non-smoker N = 520	SMD
Age, years, median [IQR]	56 [46–65]	64 [52–73]	0.45	56 [46–64]	57 [46–66]	0.09
Male sex, n (%)	340 (64.0)	936 (44.6)	0.40	335 (64.4)	204 (39.2)	0.52
BMI, kg/m^2, median [IQR]	26.0 [23.2–29.7]	27.0 [23.9–30.9]	0.16	26.2 [23.2–29.8]	27.6 [24.2–32.0]	0.24
ARISCAT score, median [IQR]	34 [31–41]	34 [31–41]	0.11	34 [31–41]	34 [31–34]	0.00
ARISCAT group, n (%)			0.12			0.00
Intermediate (26–44)	459 (86.4)	1725 (82.1)		453 (87.1)	453 (87.1)	
High (>44)	72 (13.6)	376 (17.9)		67 (12.9)	67 (12.9)	
Preoperative SpO_2, n (%)			0.04			0.01
≥ 96 %	316 (66.0)	1267 (65.9)		313 (66.2)	308 (65.7)	
91–95 %	145 (30.3)	567 (29.5)		143 (30.2)	143 (30.5)	
< 91 %	18 (3.8)	89 (4.6)		17 (3.6)	18 (3.8)	
Respiratory infection (<30d), n (%)	73 (13.7)	166 (7.9)	0.18	67 (12.9)	57 (11.0)	0.06
Preoperative anemia, n (%)	49 (9.8)	207 (10.4)	0.02	44 (9.0)	36 (7.5)	0.06
Surgical incision, n (%)			0.06			0.04
Peripheral	130 (24.5)	456 (21.7)		396 (76.2)	404 (77.7)	
Abdominal	401 (75.5)	1645 (78.3)		124 (23.8)	116 (21.3)	
Condition surgery, n (%)			0.08			0.08
Elective	438 (82.5)	1789 (85.1)		430 (82.7)	444 (85.4)	
Urgency	62 (11.7)	216 (10.3)		61 (11.7)	54 (10.4)	
Emergency	31 (5.8)	96 (4.6)		29 (5.6)	22 (4.2)	
Planned duration of surgery, n (%)			0.01			0.05
<2 h	111 (20.9)	467 (22.2)		111 (21.3)	114 (21.9)	
2–3 h	246 (46.3)	905 (43.1)		238 (45.8)	245 (47.1)	
>3 h	174 (32.8)	729 (34.7)		171 (32.9)	161 (31.0)	
ASA physical status classification, n (%)			0.09			0.17
I	77 (14.5)	285 (13.6)		77 (14.8)	99 (19.1)	
II	264 (49.7)	974 (46.5)		260 (50.0)	254 (48.9)	
III	168 (31.6)	741 (35.4)		162 (31.2)	156 (30.1)	
IV	21 (4.0)	91 (4.3)		20 (3.8)	10 (1.9)	
V	1 (0.2)	3 (0.1)		1 (0.2)	0 (0.0)	
Functional status, n (%)			0.14			0.00
Independent	479 (90.2)	1798 (85.6)		475 (91.3)	475 (91.3)	
Partially dependent	44 (8.3)	259 (12.3)		39 (7.5)	39 (7.5)	
Totally dependent	8 (1.5)	43 (2.0)		6 (1.2)	6 (1.2)	
Comorbidities, n (%)						
Heart failure	33 (6.2)	218 (10.4)	0.15	31 (6.0)	39 (8)	0.06
COPD	105 (19.8)	147 (7.0)	0.38	101 (19.4)	28 (5)	0.43
OSAS	17 (3.2)	51 (2.4)	0.04	16 (3.1)	17 (3)	0.01
Chronic kidney failure	24 (4.5)	136 (6.5)	0.08	22 (4.2)	22 (4.2)	0.00
Liver cirrhosis	17 (3.2)	25 (1.2)	0.14	17 (3)	7 (1.3)	0.13
Neuromuscular disease	3 (0.6)	18 (0.9)	0.03	3 (0.6)	5 (1.0)	0.04
Active cancer	41 (7.7)	216 (10.3)	0.09	39 (8)	42 (8.1)	0.02
Preoperative red blood cell transfusion, n (%)	12 (2.3)	47 (2.2)	0.00	10 (1.9)	7 (1.3)	0.05
Units of red blood cells transfused, median [IQR]	2 [1–2.5]	[2 [1.5–2]	0.03	2 [1–2]	2 [1–2]	0.07
Surgical procedure, n (%)						
Lower GI	101 (19.0)	470 (22.4)	0.08	97 (18.7)	112 (21.5)	0.07
Upper GI	126 (23.7)	440 (20.9)	0.07	125 (24.0)	101 (19.4)	0.11
Vascular	31 (5.8)	68 (3.2)	0.13	30 (5.8)	14 (2.7)	0.15
Aortic	15 (2.8)	30 (1.4)	0.10	15 (2.9)	6 (1.2)	0.12
Neurosurgery	20 (3.8)	84 (4.0)	0.01	20 (3.8)	21 (4.0)	0.01
Head and neck	40 (7.5)	128 (6.1)	0.05	39 (7.5)	37 (7.1)	0.01
Urological and kidney	74 (13.9)	293 (13.9)	0.00	74 (14.2)	63 (12.1)	0.06
Gynecological	44 (8.3)	296 (14.1)	0.18	44 (8.5)	84 (16.2)	0.24
Endocrine surgery	5 (0.9)	24 (1.1)	0.02	5 (1.0)	3 (0.6)	0.04
Transplant	1 (0.2)	27 (1.3)	0.13	1 (0.2)	4 (0.8)	0.08
Plastic, cutaneous, breast	22 (4.1)	86 (4.1)	0.00	21 (4.0)	25 (4.8)	0.04
Orthopedic	46 (8.7)	200 (9.5)	0.03	42 (8.1)	46 (8.8)	0.03
Other	19 (3.6)	59 (2.8)	0.12	19 (3.7)	17 (3.3)	0.02
Surgical technique, n (%)			0.04			0.05
Open	405 (76.3)	1562 (74.3)		394 (75.8)	382 (73.5)	
Minimally invasive	126 (23.7)	539 (25.7)		126 (24.2)	138 (26.5)	

Abbreviations: BMI: Body Mass Index; ARISCAT: Assess Respiratory Risk in Surgical Patients in Catalonia; PPCs: Postoperative Pulmonary Complications; SpO2: Blood Oxygen Saturation; ASA: American Society of Anesthesiologists; COPD: Chronic Obstructive Pulmonary Disease; Obstructive Sleep Apnea Syndrome; GI: Gastrointestinal.

differ between smokers compared to non–smokers; [2] regarding individual PPCs, respiratory failure occurred more frequently among current smokers compared to non-smokers; and [3] there were no differences in length of hospital stay and in–hospital mortality.

Our findings are consistent with those of previous studies, where no association between smoking and postoperative outcomes was found [4,5,14]. Several potential factors could have contributed to the absence of overall difference in PPCs between smokers and non-smokers in our cohort. First, the association between preoperative smoking status and outcomes in patients at increased risk for PPCs has not been extensively studied yet. Patients with higher ARISCAT scores often present with pre-existing comorbidities, which could already predispose them to a

Table 2
Intraoperative characteristics unmatched and matched cohorts.

	Unmatched cohort			Matched cohort		
	Smoker N = 531	Non-smoker N = 2101	SMD	Smoker N = 520	Non-smoker N = 520	SMD
Tidal volume per PBW, ml•kg^{-1}, median [IQR]	8.1 [7.2–9.1]	8.2 [7.4–9.2]	0.14	8.1 [7–9]	8.4 [7–9]	0.19
Peak pressure, cmH_2O, median [IQR]	19 [16–22]	19 [16–22]	0.05	19 [16–22]	19 [16–22]	0.06
Plateau pressure, cmH_2O, median [IQR]	17 [14–19]	17 [14–20]	0.11	17 [14–19]	17 [14–20]	0.09
PEEP, cmH_2O, median [IQR]	5 [2–5]	5 [2–5]	0.01	5 [2–5]	4 [1–5]	0.01
Driving pressure, cmH_2O, median [IQR]	12 [10–16]	13 [10–16]	0.13	12 [10–16]	12 [10–16]	0.08
Respiratory rate, breaths•min, median [IQR]	12 [12–13]	12 [12–13]	0.05	12 [12–13]	12 [12–13]	0.03
FiO_2, %, median [IQR]	50 [43–60]	50 [45–60]	0.02	50 [43–60]	50 [44–60]	0.00
SpO_2, %, median [IQR]	99 [98–100]	99 [98–100]	0.03	99 [98–100]	99 [98–100]	0.01
$EtCO_2$, kPa, median [IQR]	34 [31–36]	33 [30–36]	0.05	34 [31–36]	34 [31–36]	0.02
Recruitment maneuvers, n (%)	74 (14.1)	263 (12.6)	0.04	73 (14.2)	73 (14.1)	0.00
Duration of surgery, min, median [IQR]	135 [70–201]	133 [79–200]	0.06	133 [70–200]	130 [78–192]	0.04
Duration of anaesthesia, min, median [IQR]	170 [105–245]	175 [110–250]	0.00	170 [105–245]	170 [110–235]	0.04
Epidural anaesthesia, n (%)	75 (14.1)	302 (14.4)	0.01	72 (13.8)	74 (14.2)	0.01
Neuromuscular blockade, n (%)	503 (95.1)	1978 (94.6)	0.02	492 (95.0)	491 (95.0)	0.00
Total fluids in, L, median [IQR]	1.7 [1.1–2.5]	1.8 [1.0–2.6]	0.02	1.8 [1.0–2.6]	1.8 [1.0–2.5]	0.03
Crystalloids, L	1.5 [1.0–2.2]	1.5 [1.0–2.2]	0.03	1.5 [1.0–2.1]	1.5 [1.0–2.1]	0.00
Colloids, L	0.5 [0.5–0.9]	0.5 [0.5–0.6]	0.07	0.5 [0.5–0.9]	0.5 [0.5–0.6]	0.05
Transfusion of packed red blood cells, n (%)	42 (7.9)	204 (9.7)	0.06	40 (7.7)	41 (7.9)	0.01
Units of red blood cell transfused, median [IQR]	2 [1–2]	2 [1–3]	0.08	2 [1–2]	2 [1–2]	0.01

Abbreviations: PBW: Predicted Body Weight; PEEP: Positive End-Expiratory Pressure; FiO_2: Fraction of Inspired Oxygen; SpO_2: Oxygen Saturation; $EtCO_2$: End-tidal Carbon Dioxide.

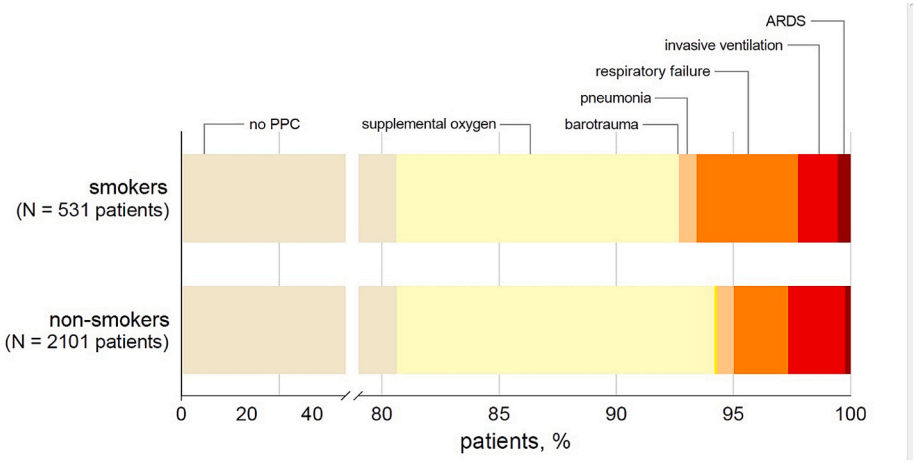

Fig. 2. Distribution plot for postoperative pulmonary complications between smokers and non-smokers.

Table 3
Outcomes according to smoking status in unmatched cohort.

	Unmatched cohort			Matched cohort		
	Smoker N = 531	Non-smoker N = 2101	*p*-value	Smoker N = 520	Non-smoker N = 520	*p*-value
Total PPC, n (%)	101 (19.0)	404 (19.2)	0.95	99 (19.0)	87 (16.7)	0.37
Mild PPC						
Unplanned supplementary oxygen	64 (12.1)	285 (13.6)	0.39	63 (12.1)	63 (12.1)	1.00
Severe PPCs	37 (7.0)	119 (5.7)	0.26	36 (6.9)	24 (4.6)	0.14
Respiratory failure	27 (5.1)	63 (3.0)	0.02	26 (5.0)	11 (2.1)	0.018
Need for invasive mechanical ventilation	9 (1.7)	52 (2.5)	0.34	9 (1.7)	11 (2.1)	0.82
ARDS	3 (0.6)	5 (0.2)	0.21	3 (0.6)	0 (0.0)	0.25
Pneumonia	6 (1.1)	22 (1.0)	0.82	5 (1.0)	5 (1.0)	1.00
Pneumothorax	1 (0.2)	3 (0.1)	1.00	0 (0.0)	1 (0.2)	1.00
Length of hospital stay, days, median [IQR]	4 [1–7]	4 [1–7]	0.79	4 [1–7]	4 [1–5]	0.82
In-hospital mortality, n (%)	4 (0.8)	36 (1.8)	0.16	4 (0.8)	4 (0.8)	1.00

Abbreviations: PPC: Postoperative Pulmonary Complication; ARDS: Acute Respiratory Distress Syndrome.

heightened risk of respiratory complications irrespective of their smoking status. Additionally, increased risk patients are likely to receive more intensive perioperative care and monitoring aimed at reducing their elevated risk for PPCs. Consequently, in this increased risk population, the additional risk from smoking may be less evident.

In contrast, a meta-analysis investigating preoperative smoking

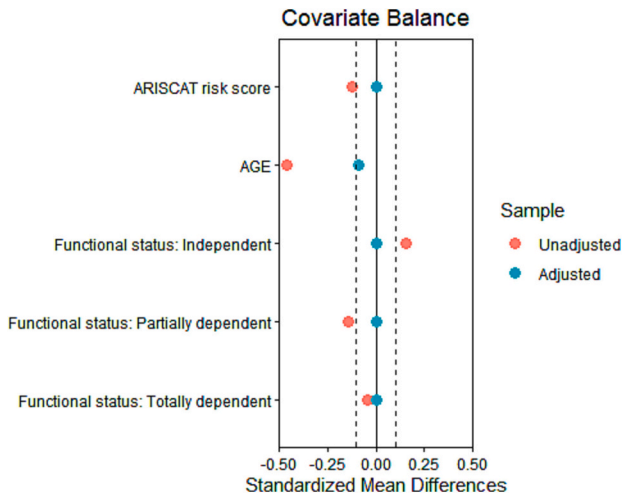

Fig. 3. LOVE-plot illustrating covariate balance between smokers and non-smokers before and after propensity score matching.

status and postoperative complications concluded that current smoking is associated with a nearly 2.5-fold increase in the risk of developing PPCs compared with non-smokers (RR = 2.46, 95 % CI: 1.74–3.48) [1]. The difference in the outcome of PPCs compared to our study can be based on several factors. The meta-analysis was limited by a significant level of heterogeneity among the included studies focussing on pulmonary complications, due to inclusion of both cardiac and non-cardiac studies, variations in in the follow up durations and different definitions of PPCs. Given the heterogeneity in the definition of PPCs, the overall occurrence of PPCs among smokers varies greatly. Some studies only restrict to severe pulmonary complications including pneumonia or respiratory failure or acute respiratory stress syndrome [15–17], whereas others include more minor complications [18]. This possibly contributes to the wide range of reported PPC incidences in smokers, varying from 3.5 % to 37 %, making it difficult to compare outcomes between studies [19].

Although the effect of smoking on overall PPCs remains unclear in patients at increased risk for PPCs, we found that smokers have a higher occurrence of respiratory failure compared to non-smokers. It is well-established that smoking impairs respiratory health through both acute exposure and chronic cumulative effects, resulting in individuals being more susceptible to perioperative pulmonary complications [20]. Consequently, smoking remains an additional risk factor in the perioperative period [1,21]. Cessation of smoking prior to surgery is known to reduce the risk of PPCs, with a benefit that increases with the length of the cessation period before surgery [12]. Therefore, anaesthesiologists should emphasize that cessation of smoking is a critical intervention to reduce surgical risks and improve long-term health outcomes and should be actively pursued in the preoperative period [24]. [12].

For future studies, it is important to keep in mind that the incidence of PPCs in patients who use e-cigarettes has yet to be explored. Over recent years, the increase in e-cigarette usage has presented a potential risk factor for postoperative complications, given its association with acute lung injury and respiratory failure [22,23]. In LAS VEGAS, no data on e-cigarette use was collected. Therefore, further studies are needed to assess the impact of e-cigarette use on postoperative outcomes.

This study has several strengths. First, we used data from the LAS VEGAS study, a global prospective observational study in patients undergoing various types of surgery. The study had a multicentre design, conducted in both community and academic hospitals, thereby increasing the generalizability of the findings. The narrow 1–week timeframe of the study prevented temporal changes in intraoperative ventilation management, general care, and occurrence of PPCs. The robustness of LAS VEGAS was further supported by the minimal amount of missing data and nearly complete follow–up of the outcome measures. We had an analysis plan in place before opening the database, which was strictly followed. We additionally performed propensity score matching to strengthen the reliability of our findings.

Our analysis has several limitations. First, this was a post hoc analysis of the observational LAS VEGAS study, which was not designed to assess the relationship between preoperative smoking status and postoperative outcomes. Although we adjusted for observed differences associated with PPCs through propensity score matching, we cannot rule out the possibility of yet unknown differences that may influence the findings. Second, LAS VEGAS originated from 2013. Since then, advancements in perioperative practices have been made, which could affect the applicability of our findings. Third, the preoperative smoking status was defined as smoker or non-smoker, with no further distinction between former smokers and never smokers. In addition, details on the number of pack years, lung function and timing of cessation were not recorded. Consequently, we cannot rule out that the non-smokers group may include individuals who ceased smoking shortly before undergoing surgery, potentially confounding the outcomes attributed to non-smokers. Last, our findings serve primarily as hypothesis-generating, as our findings regarding the relationship between smoking and PPCs can only imply associations rather than causation.

5. Conclusion

In this worldwide cohort of patients receiving intraoperative ventilation under general anaesthesia for surgery and at increased risk of PPCs, no difference was found in the occurrence of overall PPCs between smokers and non-smokers. However, compared to non-smokers, current smokers experienced a higher incidence of respiratory failure.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclinane.2025.111856.

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