BMC Anesthesiology

RESEARCH Open Access

Effect of positive airway pressure on obese patients undergoing surgery: a systematic review and meta-analysis

Xinyi Wang[1,2], Xizhi Chen[3] and Ju Gao[1,2*]

Abstract

This systematic review and meta-analysis (SRMA) evaluates the efficacy and safety of Positive Airway Pressure (PAP) therapy in perioperative care for obese surgical patients. We reviewed 24 studies, encompassing data up to March 23, 2023, analyzing the impacts of Continuous Positive Airway Pressure (CPAP) and Bilevel Positive Airway Pressure (BIPAP) on postoperative adverse outcomes, oxygenation, and pulmonary function. Our findings underscore the significant potential of PAP therapy in managing obese patients during the perioperative period, particularly those at substantial risk for postoperative respiratory complications. PAP therapy not only enhances oxygenation levels and lung function but also substantially reduces the incidence of atelectasis and shortens hospital stays, thereby affirming its vital role in improving perioperative outcomes for this patient population.

Keywords Positive Airway Pressure, Obesity management, Perioperative Care, Postoperative complications, Adverse outcomes

Introduction

The global incidence of obesity is on the rise, primarily as a result of changes in lifestyle and dietary choices. The World Health Organization defines obesity as a widespread metabolic disorder that is becoming a significant global public health concern [1]. It affects at least 1.9 billion people around the world, including over 650 million adults who are obese [2]. Obesity in adults is characterized by having a Body Mass Index (BMI) that exceeds 30, while morbid obesity is characterized by having a BMI that exceeds 40 [1]. Obesity is widely recognized as a risk factor for cardiovascular disease, diabetes, musculoskeletal disorders, and certain types of cancer [1].

General anesthesia causes a decrease in lung volume, resulting in atelectasis and decreased blood oxygen levels [3]. Obesity has a significant impact on lung function, leading to impaired mechanical ventilation, increased airway resistance, decreased lung capacity, and weakened respiratory muscles. Pulmonary atelectasis caused by anesthesia is more prominent in patients who are obese [4]. It can cause increased airway closure and hindered synchronization of breathing and blood flowing in the lungs [5–7]. Therefore, patients who are obese face a higher level of risk during anesthesia and surgery compared to those who are not obese [8]. Choosing a device that reduces airway blockage in obese patients during the perioperative period is crucial for improving prognostic outcomes.

Obstructive Sleep Apnoea (OSA) is a common sleep disorder characterized by repeated interruptions in

*Correspondence:
Ju Gao
gaoju_003@163.com
[1]Yangzhou University Medical College, Yangzhou 225000, China
[2]Northern Jiangsu People's Hospital Affiliated to Yangzhou University, Yangzhou, Jiangsu 225000, China
[3]The Yangzhou Clinical Medical College of Xuzhou Medical University, Yangzhou, Jiangsu 225000, China

breathing during sleep, resulting in inadequate oxygen levels. Studies have revealed that middle-aged adults with higher BMI face a significantly higher risk of sleep apnoea. In severely obese individuals, the prevalence of sleep apnoea can range from 40–90% [9]. Obstructive sleep apnea is more prevalent among obese individuals.

Positive Airway Pressure (PAP) therapy is the gold standard treatment for moderate to severe OSA [10, 11]. PAP therapy maintains upper airway patency by maintaining positive air pressure throughout the respiratory cycle, functioning as an inflatable splint. This modality encompasses Continuous Positive Airway Pressure (CPAP), Bilevel Positive Airway Pressure (BIPAP), and Positive Airway Pressure with Automatic Titration (APAP) [12, 13]. CPAP proffers a continual, stable influx of positive air pressure to the patient's airway, engineered to avert airway collapse and minimize the frequency of apnoeic episodes. BIPAP delivers two distinct pressure settings – an elevated pressure during inspiration (ipap) and a reduced pressure during expiration (epap), enabling patients to benefit from increased respiratory support during inspiration along with continuous positive pressure during expiration, thereby contributing to enhanced comfort and therapeutic outcomes. The APAP is an intelligent non-invasive ventilator autonomously adjusting the end positive pressure airway level in alignment with the patient's respiratory requirements.

Due to the strong connection between obesity and respiratory diseases, particularly the link between obesity and OSA, non-invasive oxygenation devices like CPAP have been used as interventions for obese surgical patients to reduce surgical risks and improve surgical outcomes. Most studies have focused on the effects of PAP therapy on patients with OSA, but there has been no systematic review and meta-analysis (SRMA) conducted to examine the effects of PAP therapy on the surgical treatment of obese patients. Hence, there is a need for further research to evaluate the effectiveness of PAP therapy in obese patients who are undergoing surgery. Such studies will serve to confer more precise guidelines to ascertain optimal respiratory support and postoperative outcomes for obese patients during surgical interventions and to minimize the concomitant surgical risks.

Methods

Protocol and registration

The protocol for this SRMA was registered in the International Prospective Register of Systematic Reviews (PROSPERO; CRD42023408765). This systematic review was developed and executed in compliance with the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guidelines.

Search strategy

We performed an extensive literature search utilizing the PubMed, Embase, and Cochrane databases. The search included articles that were indexed in these databases until March 23, 2023. Our initial study focused on CPAP in PAP, but in the search process, we found that the free words derived from CPAP in several major databases would include BIPAP and APAP. Therefore, we conducted a more comprehensive search. The search terms included "continuous positive airway pressure," "bilevel positive airway pressure," "surgery," "obesity," and related terms. In addition, we conducted a thorough examination of the reference lists of the articles that were included to identify any publications that may have been overlooked in the initial search. Additional relevant articles were discovered by conducting manual citation searches using Google Scholar and PubMed. The search was limited to studies conducted in the English language and involving human participants. The detailed search strategy is provided in Supplementary material 1.

Study selection and data extraction

Two reviewers independently conducted literature screening and data extraction based on the inclusion and exclusion criteria. When there were disagreements, a third reviewer was involved to reach a consensus. The inclusion and exclusion criteria were established based on the PICOS framework. The inclusion criteria were as follows: (1) patients ≥ 18 years of age; (2) patients diagnosed with obesity (BMI ≥ 30); (3) patients undergoing a surgical procedure; (4) individuals receiving PAP (CPAP, APAP, or BIPAP) therapy during the perioperative period; (5) inclusion of Randomized Controlled Trials (RCTs), Prospective Cohorts (PC), Retrospective Cohorts (RC), cross-sectional studies, or case-control studies; and (6) English language articles. The exclusion criteria were: (1) duplicate publications; (2) reviews, meta-analyses, animal experiments, case reports, case series, conference abstracts, book chapters, and dissertations; (3) inconsistency in study population, interventions, or outcome measures; and (4) unavailability of relevant data.

We have evaluated all included studies to strictly exclude duplicate publications, ensuring each study is independent and unique. For publications involving the same population but different study contents, we carefully distinguished and retained only the most representative and informative studies. For publications where relevant data were unavailable, we made every effort to contact the original authors or database administrators to obtain the necessary data. However, where complete data could not be obtained, we decided to exclude these publications to avoid potential bias due to data unavailability.

The included studies provided the following information: authors, year, country, study design, surgery type,

sample size, age, gender, BMI, PAP type, and usage. The study assessed various postoperative adverse outcomes, including length of hospital stay, in-hospital mortality, unplanned ICU admission rate, reintubation, reoperation, anastomotic leak, nausea and vomiting, and pulmonary complications such as atelectasis, respiratory failure, and pneumonia. The secondary outcome measures included pulmonary function (Forced Expiratory Volume in one second (FEV_1), Forced Vital Capacity (FVC), Peak Expiratory Flow Rate (PEFR)), blood gas analysis parameters (PH, PaO_2, $PaCO_2$), SpO_2 and PaO_2/FiO_2 (Fraction of Inspired Oxygen).

Methodological quality assessment

The reporting methodology was assessed independently by two reviewers, and any disagreements were resolved by a third reviewer. The quality assessment of observational studies was conducted using the New-Castle Ottawa Scale (NOS) [14]. The NOS assesses the risk of bias in observational studies across three domains: selection of cohorts, comparability of cohorts, and outcome assessment. Studies were scored on a scale from 1 to 9, with a maximum score of 9 (Supplementary material 2).

For the appraisal of RCTs, the Risk of Bias 2 (ROB 2.0) tool was applied [15]. The ROB 2.0 tool is formulated to evaluate the risk of bias arising from the randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result. It takes into consideration five domains: (1) bias arising from the randomization process, (2) bias due to deviations from intended interventions, (3) bias due to missing outcome data, (4) bias in measurement of the outcome, and (5) bias in selection of the reported result. Through this tool, each trial is evaluated in the domains, culminating in an overall risk of bias judgment that categorizes the study as having a high, low, or some concerns regarding the risk of bias. Notably, due to the intervention nature concerning the application of PAP therapy, blinding of participants to the administered treatment was unfeasible in all RCTs (Supplementary material 3).

Statistical analysis

We conducted statistical analysis using Cochrane Review Manager (RevMan, version 5.4) [16]. Our primary objective was to evaluate the efficacy of Positive Airway Pressure (PAP) therapy in reducing postoperative adverse outcomes in obese patients. Additionally, we assessed the impact of PAP therapy on various secondary endpoints, including pulmonary function measures (FEV_1, FVC, PEFR), blood gas analysis parameters (pH, PaO_2, $PaCO_2$), SpO_2, and the PaO_2/FiO_2 ratio. Risk ratios (RR) with corresponding 95% confidence intervals (CI) were used to assess dichotomous outcomes (in-hospital mortality, unplanned ICU admission rates, reintubation, reoperation, anastomotic leak, nausea and vomiting, and pulmonary complications). Standard mean differences (SMD) with 95% CIs were used to assess continuous outcomes (length of hospital stay and secondary endpoints). The Mantel-Haenszel (M-H) method was used for dichotomous events and the Inverse Variance (IV) method was used to represent continuous events. Heterogeneity was explored using a random effects model. Heterogeneity was examined across the studies for every postoperative complication by calculating I^2. The results were graphically presented in the form of forest plots. A P-value of less than or equal to 0.05 was considered statistically significant. Furthermore, to explore potential sources of heterogeneity more thoroughly, we plan to conduct subgroup analyses. We categorize the studies based on factors such as study design, sample characteristics, and intervention measures, and perform statistical analyses separately for each subgroup. This will help us understand the impact of distinct factors on study outcomes more deeply and reduce potential heterogeneity.

We performed a detailed power analysis using EBM Helper [17, 18]. To ensure the validity of the study, we used the tool to estimate the power of the test for each primary and secondary outcome measure, ensuring that statistically significant differences could be effectively detected.

Results

The initial literature search yielded 767 articles (Fig. 1). After removing 154 duplicate studies, 613 studies were screened. Following the title and abstract screening, 572 studies were eliminated from consideration because they did not meet the predetermined criteria for inclusion. The complete texts of the remaining 41 articles were evaluated to determine their eligibility. Out of the 41 studies included, 24 studies fulfilled the criteria for conducting a meta-analysis [19–42].

Study characteristics

The study characteristics and demographic data are summarized in Table 1. Most studies were conducted in Western countries ($n=19$), including the United States ($n=5$) [21, 24, 32, 34, 39], Canada ($n=3$) [40–42], Sweden ($n=2$) [25, 29], the Netherlands ($n=2$) [23, 38], Portugal ($n=1$) [28], the United Kingdom ($n=1$) [36], Belgium ($n=1$) [33], Brazil ($n=1$) [22], Poland ($n=1$) [27], Greece ($n=1$) [20], and Finland ($n=1$) [31]. Additionally, there were studies from Eastern countries ($n=5$), including Egypt ($n=2$) [26, 30], Turkey ($n=1$) [19], India ($n=1$) [37], and China ($n=1$) [35].

14 were RCTs [19–22, 24–30, 33, 37, 42], 8 were retrospective cohort studies [23, 31, 34–36, 38, 39, 41], and the remaining 2 were prospective cohort studies [32, 40]

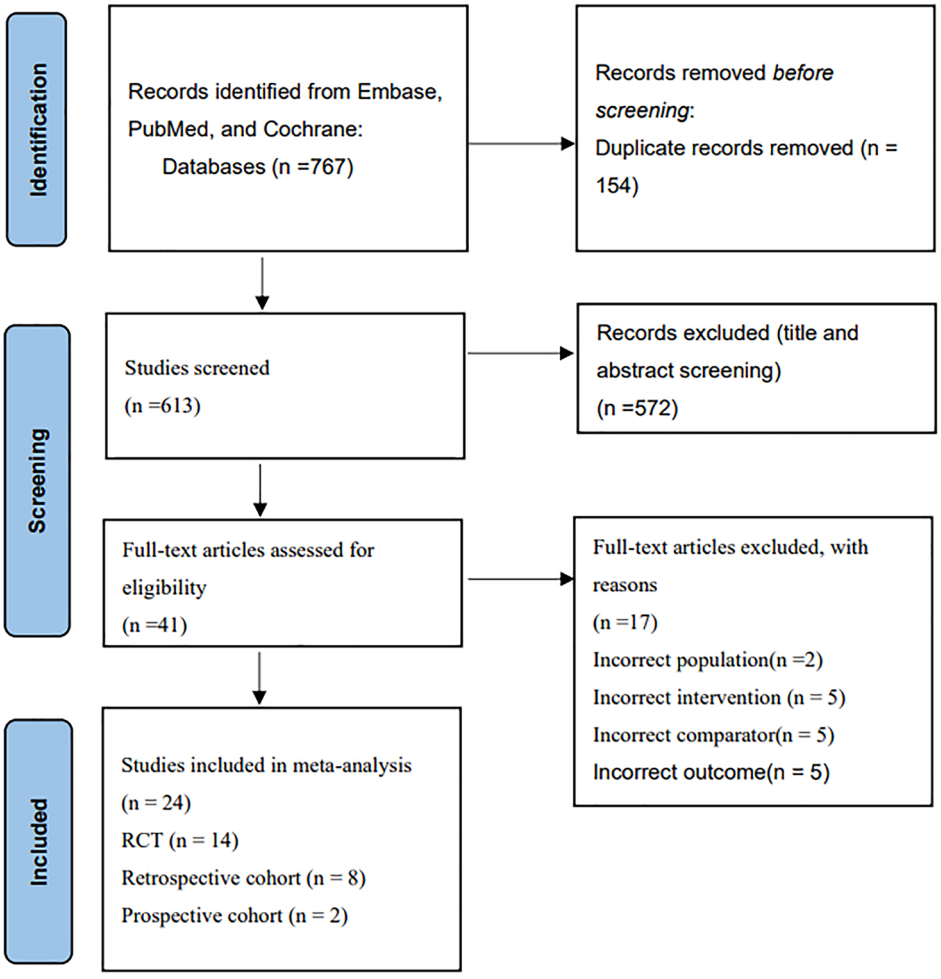

Fig. 1 PRISMA flow diagram

(Table 1). The control groups in the RCTs consisted of patients receiving conventional oxygen therapy (masks or nasal catheters). For the observational studies, the control groups were defined as patients who did not receive PAP therapy.

The studies were divided into preoperative intervention group (Pre, $n=9$) [21, 22, 25, 29, 32, 35, 37, 38, 41], postoperative intervention group (Pos, $n=16$) [19, 22, 24, 26–28, 30, 31, 33, 35, 38–40, 42], and perioperative group (Per, $n=2$) [34, 36]. Among them, two studies used CPAP both preoperatively and postoperatively [35, 38], one study analyzed the effects of preoperative and postoperative BIPAP separately [22], and two studies did not specify the timing of the intervention and were included in the perioperative group [34, 36]. The preoperative intervention group referred to interventions performed before the completion of surgery and further subdivided into preoperative ward intervention group ($n=5$) [22, 32, 35, 38, 41], preoxygenation group ($n=2$) [25, 29], and intraoperative intervention group ($n=2$) [21, 37]. 1981 patients were included in the preoperative intervention group, with 764 patients receiving PAP treatment and 1217 not using PAP treatment. The postoperative intervention group refers to the implementation of intervention measures after the surgical procedure. Among them, three studies initiated the intervention immediately after extubation [28, 41, 42]. 5080 patients were included in the postoperative intervention group, with 1304 patients receiving PAP treatment and 3776 not receiving PAP treatment. In the perioperative group, 405 patients were included, with 330 receiving PAP treatment and 75 not receiving PAP treatment (Table 1).

Postoperative adverse outcome

Length of stay

A total of nine studies evaluated the impact of PAP therapy on hospital length of stay (LOS) in obese patients undergoing invasive surgery (Pre, $n=3$ [28, 38, 40]; Pos, $n=6$ [24, 31, 32, 36, 38, 41], Per, $n=1$ [34]). The results showed a statistically significant difference

Table 1 Study characteristics

Study	Study type	Country	Study period	Surgery	Interventions time	Obese patients		PAP Type	Sex		Age	BMI
						PAP	NO PAP		male	female	PAP/NO PAP	PAP/NO PAP
Bai, 2019	RCT	USA	June 2017 - October 2017	Colonoscopy	Pre	63	73	CPAP	56	80	/	36 ± 5/36 ± 6
Harbut, 2014	RCT	Sweden	January 10, 2009 - March 31, 2009	LGB	Pre	24	24	CPAP	/	/	46.9 ± 12.9/42.1 ± 12.4	43 ± 6.3/44.1 ± 6.0
Edmark, 2016	RCT	Sweden	March 21, 2012 - March 19, 2014	LGB	Pre	20	20	CPAP	8	32	38.28 ± 7.98/41.92 ± 8.78	42.08 ± 3.91/38.5 ± 4.07
Munaf, 2020	RCT	India	January 2015 - May 2016	Surgeries under spinal anesthesia	Pre	63	63	CPAP	52	75	39.7 ± 9.01/38.06 ± 9.1	26.63 ± 1.11/26.34 ± 1.03
Jensen, 2008	PC	USA	January 2003 - December 2007	LRYGB	Pre	144	140	CPAP/BPAP	80	204	47 ± 11/44 ± 10	49 ± 12.25/47 ± 10.5
Sériès, 2020	RC	Canada	January 1, 2014 - May 31, 2015	LSG and BPD/DS	Pre	239	39	CPAP	111	167	47.7 ± 10.60/43.5 ± 12.2	50.52 ± 8.16/48.7 ± 6.8
Gaszynski, 2007	RCT	Poland	/	RYGB	Pos	10	9	CPAP	8	11	35.84 ± 9.05	42.43 ± 3.3
Guimarães, 2016	RCT	Portugal	October 2014 - November 2014	RYGB	Pos	11	12	CPAP	4	19	41.82 ± 6.98/44.75 ± 12.28	43.35 ± 5.56/43.49 ± 6.49
Wong, 2011	RCT	Canada	/	RYGB	Pos	43	38	CPAP	24	57	42.9 ± 10.1/46.3 ± 10.4	50.5 ± 8.4/ 49.5 ± 8.2
Kizilöz, 2012	RCT	Turkey	/	Laparoscopic cholecystectomy	Pos	20	20	CPAP	29	11	46.90 ± 13.16/48.55 ± 10.32	32.37 ± 2.42/32.60 ± 1.94
Hewidy, 2016	RCT	Egypt	April 2013 - October 2015	SG	Pos	24	22	CPAP	19	27	31.25 ± 10.36/26.86 ± 5.90	58.89 ± 9.46/55.89 ± 8.09
Javanainen, 2016	RC	Finland	2008–2011	SG/RYGB	Pos	100	100	CPAP	72	128	47.90 ± 8.8/47.80 ± 8.8	48.9 ± 6.7/ 48.9 ± 6.8
de Raaff, 2017	RC	Netherlands	November 2007 - August 2016	BS (RYGB, SG, SADI-S)	Pos	497	1638	CPAP	1747	388	44.34 ± 11.18	44.12 ± 6.55
Sériès, 2021	PC	Canada	January 1,2014 - January 7, 2018	BPD-DS/LSG	Pos	289	805	CPAP	231	863	49.7 ± 10/41.80 ± 10.79	49.3 ± 8.7/46.59 ± 7.13
Ramirez, 2009	RC	USA	June 2005 - August 2006	LRYGB	Pos	91	219	CPAP	/	/	47.2/43.9	52/46.4
Kong, 2016	RC	USA	2005–2009	BS	Per	305	47	CPAP	110	242	47.47 ± 0.63/48.02 ± 1.70	49.7 ± 0.55/48.7 ± 1.68
Meng, 2010	RC	China	January 2001 - December 2005	RYGB	Pre + Pos	102	254	CPAP	281	76	46.5 ± 0.4	51.5 ± 0.3

Table 1 (continued)

Study	Study type	Country	Study period	Surgery	Inter-ventions time	Obese patients		PAP Type	Sex		Age	BMI
						PAP	NO PAP		male	female	PAP/NO PAP	PAP/NO PAP
Meurgey, 2017	RC	Britain	June 2014 - March 2017	SG/RYGB	Per	25	28	CPAP	9	44	48.5 ± 11.4	49.7 ± 10.4/49.1 ± 5.9
Proczko, 2014	RC	Netherlands	January 2009 - November 2013	RYGB/LSG	Pre + pos	99	594	CPAP	486	207	44.5 ± 7.0/46.18 ± 5.65	42.6 ± 2.6/ 43.29 ± 2.83
Alexandropoulou, 2019	RCT	Greece	/	OBS	Pos	21	14	BPAP	20	15	33 ± 8/31 ± 6	53 ± 8/52 ± 6
Baltieri, 2014	RCT	Brazil	/	OBS	Pre/Pos	10Pre/10Pos	10	BPAP	24	6	42 ± 11.2Pre/38.8 ± 9.6Pos/ 42.6 ± 11.6	44.8 ± 2.8Pre/46.8 ± 4.6Pos/44.4 ± 2.8
El-Sayed, 2012	RCT	Egypt	April 2009 - October 2010	LBS	Pos	18	19	BPAP	7	49	35 ± 6/33.5 ± 3.52	54 ± 3/53.5 ± 2.04
EBEO, 2002	RCT	USA	August 1999 - May 2000	ORYGB	Pos	9	12	BPAP	1	20	37 ± 6/35 ± 10	50 ± 7/47 ± 5
]Oris, 1997	RCT	Belgium	/	Gastroplasty	Pos	10	10	BPAP	5	15	33.4 ± 12.3/31.4 ± 8.7	/

LGB: Laparoscopic Gastric Bypass, LRYGB: Laparoscopic Roux-en-Y Gastric Bypass, RYGB: Roux-en-Y Gastric Bypass, SG: Sleeve Gastrectomy, LSG: Laparoscopic Sleeve Gastrectomy, BPD/DS: Biliopancreatic Diversion with Duodenal Switch, SADI-S: Single - Anastomosis Duodenal-Ileal Bypass with Sleeve Gastrectomy, BS: Bariatric Surgery, OBS: Open Bariatric Surgery, ORYGB: Open Roux-en-Y Gastric Bypass, CPAP: Continuous Positive Airway Pressure, BPAP: Bilevel Positive Airway Pressure, Pre: preoperative intervention, Pos: postoperative intervention, Per: perioperative

in LOS between obese patients who received PAP therapy (n=1221) and those who did not receive PAP therapy (n=1777) (SMD: 0.35, 95% CI: 0.04–0.64, P<0.01, I^2=89%) (Fig. 2 Panel A1). There was significant heterogeneity among the study results (I2=89%), so a sensitivity analysis was performed by excluding one study [34] that deviated significantly, resulting in no heterogeneity (SMD: 0.20, 95% CI: 0.07–0.33, P=0.04, I^2=20%) (Fig. 2 Panel A2). There may be many reasons for the heterogeneity of the overall results in Kong's study. LOS may be correlated with factors such as the level of stress on hospital beds, the expertise of doctors, the overall condition of patients, and other related variables. Even the inevitable selection bias in the inclusion of patients in this study as a retrospective cohort study may be one of the reasons for the heterogeneity.

In-hospital mortality

Three studies investigated the impact of PAP on in-hospital mortality in obese patients receiving perioperative treatment (Pre, n=2 [38, 40]; Pos, n=2 [32, 38]). We found no difference in postoperative in-hospital mortality between obese patients who used PAP (n=532) and those who did not (n=1539) (OR: 3.00, 95% CI: 0.33–27.03, I^2=0%, P=0.39) (Fig. 2 Panel B).

Unplanned ICU admission

We analyzed six studies that documented unplanned ICU admission rates for obese patients following surgery(Pos, n=5 [28, 35, 38, 40, 42]; Pre, n=2 [35, 38, 41]). We found no difference in postoperative unplanned ICU admission between obese patients who used PAP (n=783) and those who did not (n=1742) (OR: 0.55, 95% CI: 0.26–1.18, I^2=0%, P=0.91) (Fig. 2 Panel C).

Reintubation

We included five studies that reported the incidence of reintubation in obese patients after surgery (Pos, n=4 [28, 35, 38, 42]; Pre: n=3 [32, 35, 38]). The results showed that there was no significant difference in the incidence of reintubation between patients receiving PAP treatment (n=399) and those not receiving PAP treatment (n=1038) (OR: 0.40, 95% CI: 0.11–1.53, I^2=0%, P=0.99) (Fig. 2 Panel D).

Reoperations

We included three studies that reported the incidence of reoperation in obese patients after surgery (Pos, n=2) [31, 40]; Pre, n=1 [41]). The results showed that there was no significant difference in the incidence of reoperation between patients receiving PAP treatment (n=628) and those not receiving PAP treatment (n=944) (OR: 1.81, 95% CI: 0.92–3.58, I^2=0%, P=0.62) (Fig. 2 Panel E).

Anastomotic leakage

We included four studies that reported the incidence of anastomotic leak in obese patients after surgery (Pos, n=3 [23, 39, 40]; Pre, n=1 [32]). The results showed that

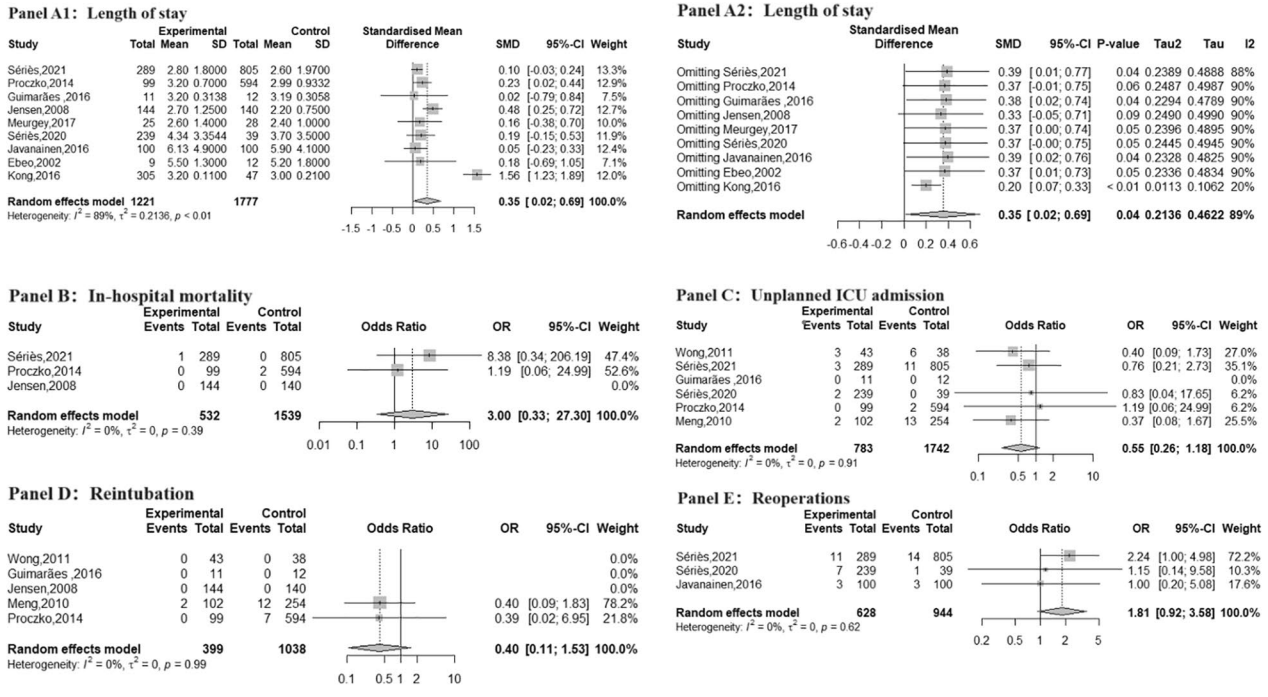

Fig. 2 Postoperative adverse outcomes. (**A**) Length of stay. (**B**) In-hospital mortality. (**C**) Unplanned ICU admission. (**D**) Reintubation. (**E**) Reoperations

there was no significant difference in the incidence of anastomotic leak between patients receiving PAP treatment ($n=1003$) and those not receiving PAP treatment ($n=2802$) (OR: 1.80, 95% CI: 0.80–4.09, $I^2=0\%$, $P=0.33$) (Fig. 3 Panel F).

Nausea and vomiting

We included two studies that reported the occurrence of nausea and vomiting in obese patients after surgery (Pos, $n=2$ [19, 35]; Pre, $n=1$ [35]). The results showed no significant difference in the incidence of nausea and vomiting between patients receiving PAP treatment ($n=122$) and those not receiving PAP treatment ($n=274$) (OR: 1.13, 95% CI: 0.66–1.93, $I^2=0\%$, $P=0.84$) (Fig. 3 Panel G).

Atelectasis

A total of six studies were included, reporting the occurrence of atelectasis in obese patients after surgery (Pos, $n=5$ [20, 22, 26, 30, 39]; Pre, $n=1$ [22]; Per, $n=1$ [34]). The results showed a statistically significant difference in the occurrence of atelectasis between patients receiving PAP treatment ($n=479$) and those not receiving PAP treatment ($n=350$) (OR: 0.22, 95% CI: 0.07–0.72, $I^2=46\%$, $P=0.10$) (Fig. 3 Panel H1).

Of the six studies, only two showed a statistically significant difference between PAP treatment and reduced rates of atelectasis. When subgroup analysis was performed based on the type of PAP treatment (BIPAP versus CPAP), the results showed a statistically significant reduction in atelectasis in the BIPAP group, while the CPAP group did not show a statistically significant difference but was more heterogeneous ($I^2=71\%$) (Fig. 3 Panel H1). Through sensitivity analysis, it was found that the heterogeneity came from the study of Ramirez [39] (Fig. 3 Panel H2). In this study, the incidence of atelectasis increased instead of decreasing in PAP group. This may be because the study, as a retrospective cohort study, has inherent potential for selection bias. In addition, there were statistically significant differences in age and BMI between the two groups in this study, so the comparability between the groups was poor. This difference in underlying health conditions may also be a key factor in the difference in treatment outcomes. After exclusion of this study, CPAP group heterogeneity disappeared and showed a statistically significant reduction in the incidence of atelectasis (OR: 0.12, 95% CI: 0.05–0.32, $I^2=0\%$, $P=0.96$) (Fig. 3 Panel H3).

Respiratory failure

A total of three studies were included, reporting the occurrence of respiratory failure in obese patients after surgery (Pos, $n=2$ [30, 40]; Per, $n=1$ [26]). The results

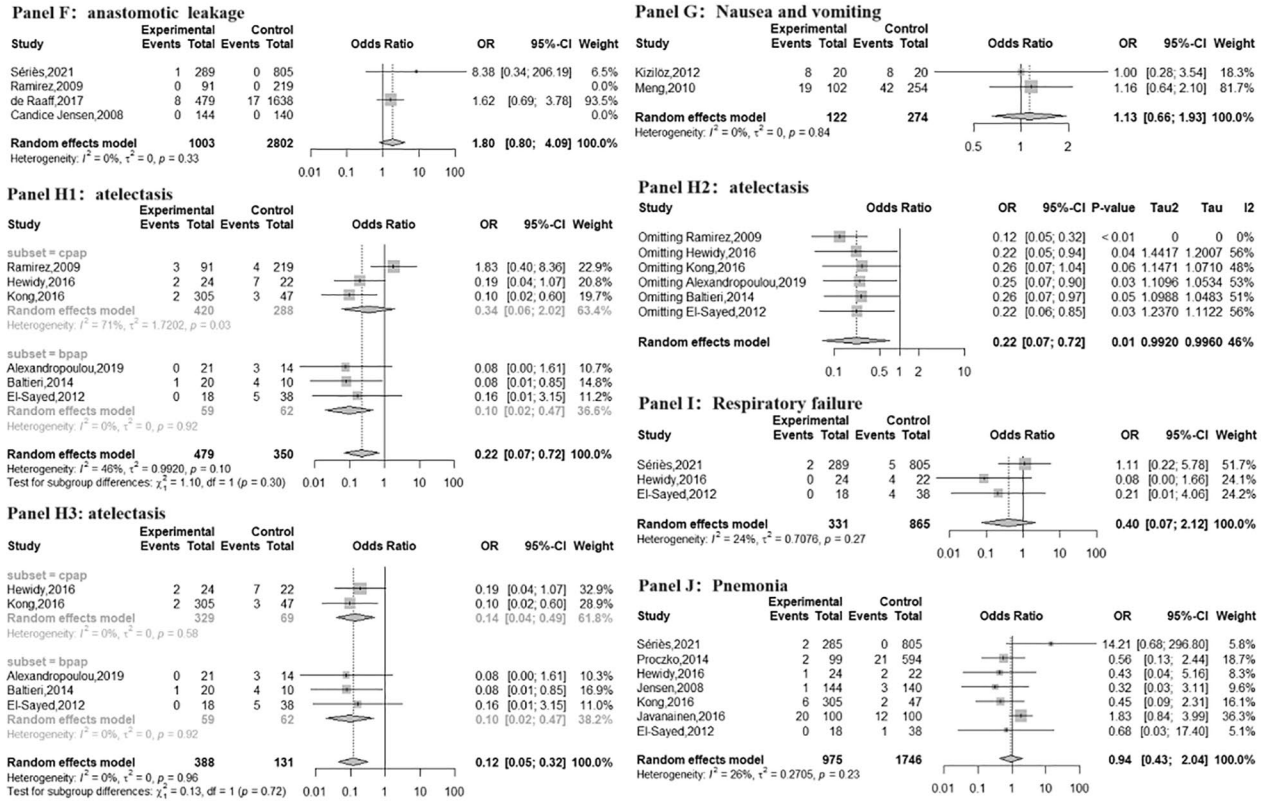

Fig. 3 Postoperative adverse outcomes. (**F**) anastomotic leakage. (**G**) Nausea and vomiting. (**H**) atelectasis. (**I**) Respiratory failure. (**J**) Pneumonia

showed no statistically significant difference in the occurrence of respiratory failure between patients receiving PAP treatment (n=331) and those not receiving PAP treatment (n=865) (OR: 0.40, 95% CI: 0.07–2.12, I^2=24%, P=0.27) (Fig. 3 Panel I).

Pneumonia

A total of seven studies were included, reporting the occurrence of pneumonia in obese patients after surgery (Pos, n=5 [26, 30, 31, 38, 40]; Pre, n=2 [26, 38]; perioperative group, n=1 [34]). The results showed no statistically significant difference in the occurrence of pneumonia between patients receiving PAP treatment (n=975) and those not receiving PAP treatment (n=1746) (OR: 0.94, 95% CI: 0.43–2.04, I^2=30%, P=0.23) (Fig. 3 Panel J).

The secondary outcome measures

Pulmonary function (FEV_1, FVC, PEFR)

A total of six studies evaluated the effects of PAP treatment on postoperative FEV_1 in obese patients (Pos, n=5 [24, 26, 28, 30, 33]; Pre, n=1 [37]). The results showed a statistically significant difference between patients receiving PAP treatment (n=135) and those not receiving PAP treatment (n=157) (SMD: 0.44, 95% CI: 0.09–0.80, I^2=46%, P=0.10) (Fig. 4 Panel K).

Seven studies assessed the effects of PAP treatment on postoperative FVC in obese patients [postoperative intervention group (n=6) [22, 24, 26, 28, 30, 33]; preoperative intervention group (n=2) [22, 37]]. The results demonstrated a statistically significant difference between patients receiving PAP treatment (n=155) and those not receiving PAP treatment (n=167) (SMD: 0.56, 95% CI: 0.23–0.89, I^2=38%, P=0.14) (Fig. 4 Panel L).

Four studies evaluated the effects of PAP treatment on postoperative PEFR in obese patients (Pos, n=3 [24, 26,

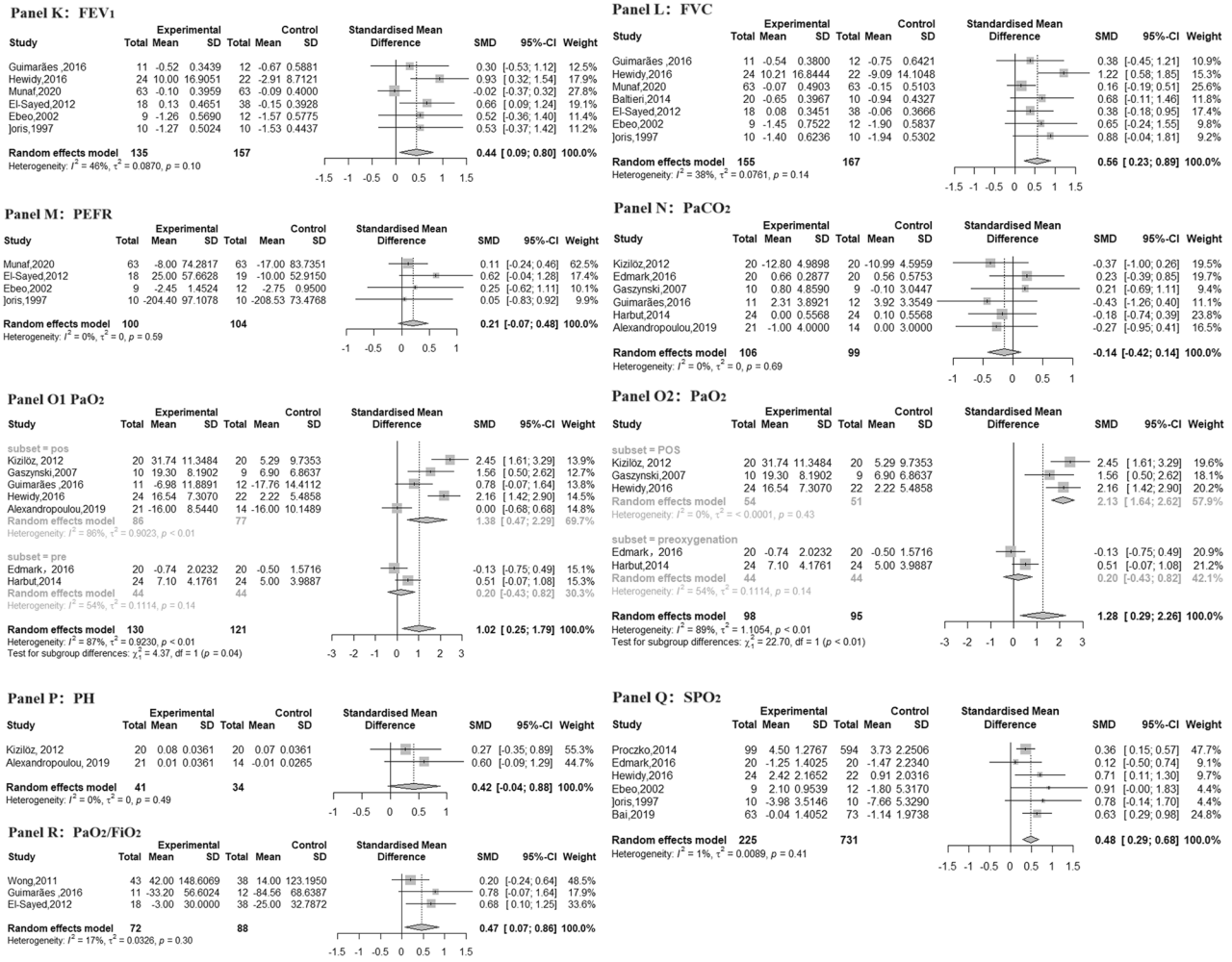

Fig. 4 pulmonary function, blood gas analysis parameters, SpO_2 and PaO_2/FiO_2. (**K**) FEV_1. (**L**) FVC. (**M**) PEFR. (**N**) PCO_2. (**O**) pO_2. (**P**) PH. (**Q**) SpO_2. (**R**) PaO_2/FiO_2

33]; Pre, n= [37]). The results indicated no statistically significant difference between patients receiving PAP treatment (n=100) and those not receiving PAP treatment (n=104) (SMD: 0.21, 95% CI: -0.07-0.48, I^2=0%, P=0.59) (Fig. 4 Panel M).

Blood gas analysis parameters ($PaCO_2$, PaO_2, PH)

A total of six studies evaluated the effects of PAP treatment on postoperative $PaCO_2$ in obese patients (Pos, n=4 [19, 20, 27, 28]; Pre, n=2 [25, 29]). The results indicated no statistically significant difference between patients receiving PAP treatment (n=106) and those not receiving PAP treatment (n=99) (SMD −0.14, 95% CI: -0.42-0.14, I^2=0%, P=0.69) (Fig. 4 Panel N).

A total of 7 studies evaluated the effects of PAP treatment on postoperative PaO_2 in obese patients (Pos, n=5 [19, 20, 27, 28, 30]; Pre, n=2 [25, 29]). The results indicated a statistically significant difference between patients receiving PAP treatment (n=130) and those not receiving PAP treatment (n=121) (SMD: 1.02, 95% CI: 0.25–1.79, I^2=87%, P<0.01) (Fig. 4 Panel O1).

Due to the observed heterogeneity in PaO_2 between the intervention and control groups, subgroup analysis was conducted based on the timing of intervention implementation. By excluding studies that applied CPAP immediately after extubation and those utilizing BIPAP [20, 28], the heterogeneity within the postoperative CPAP group [19, 27, 30], which comprised studies using CPAP during the postoperative recovery period, was eliminated(SMD: 2.13, 95% CI: 1.64–2.62, I^2=0%, P=0.43) (Fig. 4 Panel O2). The two articles that contributed to the heterogeneity may have been caused by the timing of PAP application, the duration of use, and the specific method used. Heterogeneity in the preoxygenation group [25, 29] was significantly reduced but still present (SMD: 0.20, 95% CI: -0.43-0.82, I^2=54%, P=0.14) (Fig. 4 Panel O2), due to the use of different FIO_2 levels (80% vs. 100%) and pre-oxygenation methods (combined CPAP and PSV vs. CPAP alone).

A total of 2 studies evaluated the effects of PAP treatment on postoperative PH in obese patients (Pos, n=2 [19, 20]). The results indicated that there was no statistically significant difference in PH between patients receiving PAP treatment (n=41) and those not receiving PAP treatment (n=34) (SMD: 0.42, 95% CI: -0.04-0.88, I^2=0%, P=0.49) (Fig. 4 Panel H).

SpO_2

A total of six studies evaluated the effect of PAP therapy on SpO_2 in obese patients undergoing surgery (Pos, n=4 [24, 30, 33, 38]; Pre, n=2 [25, 38]; Per, n=1 [21]). The results showed a statistically significant difference between patients who received PAP therapy (n=225) and those who did not (n=731) (SMD: 0.48, 95%CI: 0.29–0.68, I^2=0%, P=0.41) (Fig. 4 Panel Q).

PaO_2/FIO_2

A total of 3 studies evaluated the effects of PAP treatment on the ratio of arterial oxygen partial pressure to fractional inspired oxygen (PaO_2/FIO_2) in obese patients undergoing surgery (Pos, n=3 [26, 28, 42]). The results indicated that there was a statistically significant difference in the PaO_2/FIO_2 ratio between patients receiving PAP treatment (n=72) and those not receiving PAP treatment (n=88) (SMD: 0.47, 95% CI: 0.07–0.86, I^2=17%, P=0.30) (Fig. 4 Panel R).

Quality assessment

The quality assessment is described in the supplemental tables (Supplementary material 2). The studies scored at least six and a maximum of eight on Newcastle Ottawa Scale. There were two prospective and eight retrospective studies. The studies scored well in the representativeness of the exposed cohort, selection of the non-exposed cohort, ascertainment of exposure, and assessment of outcome. There were five studies which demonstrated that the outcome of interest was not present at the start of study [23, 35, 36, 39, 41]. Some studies had a small number of participants lost to follow-up, but not enough to produce bias. Most included studies defined and adjusted for main confounders and prognostic factors relevant to their study.

We assessed fourteen randomized controlled trials using the Cochrane risk of bias tool (Supplementary material 3). The domains of deviations from the intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result showed a minimal risk of bias. Nevertheless, the randomization process, which includes allocation concealment, showed an uncertain risk of bias.

Power analysis

Most outcomes, such as LOS, in-hospital mortality, ICU admission rates, reintubation, reoperations, atelectasis, FEV1, FVC, PaO_2, and SpO_2, show a power value of 1.0. This indicates that the study has sufficient power to detect significant differences or changes for these outcomes. The power value for nausea and vomiting (0.1328) is significantly below the accepted threshold of 0.8. This may be related to fewer included studies and smaller sample sizes for this outcome, suggesting that the study may lack sufficient power to detect significant differences or changes. This particularly low power could lead to a Type II error, potentially missing significant effects. Outcomes such as pneumonia (0.5128), PEFR (0.7367), $PaCO_2$ (0.5655), and PH (0.5935) exhibit moderate power values (ranging from 0.5 to 0.75), indicating a moderate

risk of Type II errors. This suggests that the study may not have captured the true impact on these outcomes, indicating the need for larger sample sizes or additional studies to confirm these findings (Fig. 5).

Discussion

This SRMA explored the relationship between PAP therapy and the reduction of postoperative adverse outcomes in obese patients. The findings of our study indicate that PAP therapy significantly decreased the likelihood of postoperative atelectasis by 78% (RR 0.22) (Fig. 3 Panel H1). Nevertheless, by excluding one study [39] that caused significant heterogeneity, the risk reduction was enhanced to 88% (RR 0.12) (Fig. 3 Panel H3). The adjusted outcome suggests that PAP therapy could be more effective than initially observed, offering a clearer representation of its potential benefits in reducing postoperative atelectasis.

While the link between obesity and an increased risk of postoperative pulmonary complications is well-documented in the literature [4–7, 43, 44], the impact of PAP therapy on these complications remains contentious. The results of our study did not show a notable benefit of PAP therapy in preventing additional pulmonary complications, such as pneumonia and respiratory failure (Fig. 3 Panel I, J). Prior studies indicated that the utilisation of CPAP could decrease the occurrence of pneumonia in comparison to conventional treatments [45]. However, a recent meta-analysis [46] examining the relationship between routine non-invasive respiratory support and postoperative pneumonia in elective surgeries indicated that such routine use does not prevent pneumonia in adults, aligning with our findings. Future studies may need larger and multicenter trials to explore the effects of PAP therapy on postoperative pulmonary complications in obese patients.

Despite the adjusted effect size of 0.22 (previously 0.35) (Fig. 2 Panel A1-2), PAP therapy continues to beneficially influence the shortening of LOS for obese surgical patients. The importance of incorporating PAP into the perioperative care protocol for obese patients, especially those at substantial risk for postoperative respiratory complications, is underscored. Hospitals and healthcare systems might consider policies supporting the routine use of PAP therapy for obese patients undergoing surgery as a strategy to enhance recovery and reduce the burden of prolonged hospital stays. This strategy is particularly impactful in settings where reducing hospital stays is a priority for resource management and patient outcomes.

Outcome	Number of references	Experimental	Control	Power Value
LOS	9	1221	1777	1
In-hospital mortality	3	532	1539	1
Unplanned ICU admission	6	783	1742	1
Reintubation	5	399	1038	1
Reoperations	3	628	944	1
anastomotic leakage	5	1003	2802	1
Nausea and vomiting	2	122	274	0.1328
Atelectasis	6	479	350	1
Respiratory failure	3	331	865	1
Pnemonia	7	975	1746	0.5128
FEV_1	6	135	157	1
FVC	7	155	167	1
PEFR	4	100	104	0.7367
$PaCO_2$	6	106	99	0.5655
PaO_2	7	130	121	1
PH	2	41	34	0.5935
SPO_2	6	225	731	1
PaO_2/FiO_2	3	72	88	0.9923

Fig. 5 Power analysis results of each outcome index

In the past, concerns about the potential for pressurized air to cause gastric and proximal bowel distension limited the use of PAP therapy in obese patients undergoing gastrointestinal surgery [47]. Despite the theoretical risk of anastomotic injury from the pressurized air delivered by PAP, recent studies have demonstrated that PAP therapy does not compromise postoperative anastomotic integrity [48]. Our findings corroborate this (Fig. 3 Panel F), indicating that PAP treatment does not increase the risk of anastomotic leaks or suture rupture, thus alleviating concerns about its perioperative use. Regarding other adverse outcomes, including in-hospital mortality, unplanned ICU admissions, reoperation rates, reintubation, and nausea and vomiting, our study showed no significant differences (Fig. 2 Panel B-E, Fig. 3 Panel G). These results support the safety and efficacy of PAP therapy, affirming its viability as a component of perioperative care for obese patients undergoing a wide range of surgeries.

Pathological obesity significantly impairs lung function, affecting mechanical ventilation, airway resistance, and lung capacity, due to increases in total and abdominal fat [49–52]. This condition not only reduces vital capacity (VC) and FEV1, but also complicates effective gas exchange, particularly in the supine position [53, 54]. These challenges often intensify following anesthesia and surgical interventions, potentially worsening pulmonary outcomes [55].

To elucidate the impact and mechanisms of PAP therapy on obese surgical patients, we conducted detailed analyses of pulmonary functions, blood gas parameters, SpO_2, and PaO_2/FiO_2 ratios.

Our findings suggest beneficial effects of PAP therapy on postoperative pulmonary indices such as FEV_1 and FVC, while effects on PEFR remain unclear (Fig. 4 Panel K-N). By improving parameters such as FEV1 and FVC, PAP therapy directly addresses the diminished lung function typical in obese patients. Obesity is associated with decreased chest wall compliance [49], which often impairs ventilation in these patients and may be associated with conditions such as hypoventilation syndrome and OSA. PAP therapy enhances lung volume and reduces intrapulmonary shunting, thereby improving ventilation and oxygenation in obese individuals. This effect is evident in our study results, which show significant improvements in PaO_2 and SpO_2 levels following PAP treatment (Fig. 4 Panel O1-O2, Q).

However, improvements in oxygenation could also be influenced by variations in the FIO_2. Therefore, some studies [26, 28, 42] employ the PaO_2/FIO_2 ratio as a principal measure, reflecting lung oxygenation across different FIO_2 levels. The pooled results from our studies indicate that the PF ratio remains significantly higher in the PAP group compared to the non-PAP group (Fig. 4 Panel R), suggesting that PAP therapy can achieve higher oxygenation levels through enhanced FIO_2 and better ventilation/perfusion matching. It is important for the patients to maintain vital organs and for easier recovery from surgery. Enhanced oxygen levels help mitigate the risk of complications such as infections and promote faster healing and recovery. There were no significant differences in $PaCO_2$ and PH levels (Fig. 4 Panel N, P), which further supports the specificity of PAP effects on targeted pulmonary outcomes without broader systemic changes.

A limitation of our study is the low or unknown level of PAP adherence in the intervention group which may limit the optimization of PAP therapy to prevent adverse postoperative outcomes. Adherence levels within the intervention groups were explicitly reported in only four studies [30, 36, 40, 41], indicating that suboptimal adherence might obscure the true therapeutic efficacy of PAP, leading to an apparent absence of benefits for certain postoperative outcomes. Future research must explore whether strict adherence to PAP significantly reduces postoperative complications and develop broader trials to identify effective strategies that enhance adherence to PAP therapy.

Second, our findings are constrained by the inclusion of some low-quality studies in the SRMA. Some studies were small-scale, retrospective, and observational, with limited evidence quality and significant heterogeneity. We acknowledge that the quality of included literature significantly impacts the results of the meta-analysis. To address this issue, we carefully reviewed and assessed all included studies, implementing stringent inclusion and exclusion criteria to maintain a high standard of evidence. We also conducted repeated evaluations of data during the inclusion process to minimize bias as much as possible. Moreover, our study's ability to assess specific controversial outcome measures such as pneumonia, respiratory failure, nausea, and vomiting is constrained due to low power values for these outcomes (Fig. 5). This limitation may have affected our understanding and interpretation of these critical clinical issues. Future studies should consider increasing the sample size or using more precise study designs to improve the ability to assess these controversial outcome measures. Although the current body of literature may not be sufficient to draw meaningful conclusions in subgroups, this does not negate the importance of SRMA. Guidelines on perioperative management of obese patients emphasize the adverse effects of obesity on postoperative outcomes. Obese patients undergoing surgery, especially those at substantial risk of OSA, should receive appropriate perioperative care, including the use of CPAP [56]. This SRMA provides necessary evidence on the efficacy of PAP in reducing adverse postoperative outcomes in

obese surgical patients, enabling further exploration of this issue, calling for research, and promoting safer patient care.

Another limitation includes the reconciling of the results of RCTs and observational studies, which remains a substantial challenge for clinical medicine. The integration of these study types into SRMA can lead to inconsistent outcomes due to differences in analytical methodologies, impacting the internal validity of the findings. The scarcity of RCTs particularly weakens the causal inference in meta-analyses concerning PAP treatment for obese patients undergoing surgery. However, observational studies continue to be invaluable, providing critical insights especially when RCTs are scarce or challenging to conduct. Furthermore, we acknowledge that the quality of literature included can significantly affect the outcomes of a meta-analysis. To address this, we have meticulously reviewed and evaluated all included studies, implementing stringent inclusion and exclusion criteria to maintain a high standard of evidence. We have also conducted repeated evaluations of data during the inclusion process to minimize the risk of bias as much as possible.

Additionally, our study incorporated only two non-invasive oxygenation devices, CPAP and BIPAP. Exploring new non-invasive oxygenation devices like Trans-nasal Humidified Rapid Insufflation Ventilatory Exchange(THRIVE) may offer better therapeutic outcomes and comfort for obese patients, expanding the scope of non-invasive oxygenation benefits in surgical care. What's more, the majority of our studies included originate from Western countries, introducing potential geographical and ethnic biases. Most of the obese patients in our studies underwent bariatric surgery, with only a few undergoing other procedures such as endoscopy, spinal anesthesia, or gallbladder surgery. This distribution may limit the applicability of our findings to non-bariatric surgical settings. For future research, there is a need to conduct larger-scale RCTs in diverse geographic settings and for diverse types of surgeries to ensure the scientific rigor and reliability of findings.

Our analysis highlights the significant potential of PAP therapy in the perioperative management of obese patients, particularly those at substantial risk for postoperative respiratory complications. PAP therapy enhances oxygenation levels and lung function and reduces atelectasis and shortens hospital stays. Incorporating PAP therapy into the standard care protocols for obese surgical patients offers a valuable strategy for improving postoperative recovery and minimizing hospitalization durations. This approach is especially impactful in settings where prioritizing the efficient use of hospital resources and optimizing patient outcomes are crucial.

Abbreviations

PAP	Positive Airway Pressure
OSA	Obstructive Sleep Apnoea
CPAP	Continuous Positive Airway Pressure
BIPAP	Bilevel Positive Airway Pressure
APAP	Positive Airway Pressure with Automatic Titration
FVC	Forced Vital Capacity
PEFR	Peak Expiratory Flow Rate
FEV_1	Forced Expiratory Volume in one second
FIO_2	Fraction of Inspired Oxygen
VC	Vital Capacity
THRIVE	Trans-nasal Humidified Rapid Insufflation Ventilatory Exchange
RCTs	Randomized Controlled Trials
PC	Prospective Cohorts
RC	Retrospective Cohorts

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12871-024-02665-9.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

Author contributions

Conceptualization: Xinyi Wang, Ju Gao; Methodology: Xinyi Wang; Formal analysis and investigation: Xinyi Wang, Xizhi Chen; Writing - original draft preparation: Xinyi Wang; Writing - review and editing: Xinyi Wang, Xizhi Chen, Ju Gao; Funding acquisition: Ju Gao. All authors read and approved the final manuscript.

Funding

This work was supported by the National Natural Science Foundation of China (82172190). The funder had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Data availability

All data is available in the manuscript.

Declarations

Ethics approval and consent to participate

No ethical approval was required for this study.

Consent for publication

For this type of study, formal consent is not required.

Competing interests

The authors declare no competing interests.

Received: 22 April 2024 / Accepted: 30 July 2024
Published online: 09 August 2024

References

1. Hathhotuwa RN, Wijeyaratne CN, Senarath U. Worldwide epidemic of obesity. 2020.
2. Obesity. and overweight [https://www.who.int/en/news-room/fact-sheets/detail/obesity-and-overweight]
3. Hedenstierna G, Rothen HU. Respiratory function during anesthesia: effects on Gas Exchange. Compr Physiol. 2012;2(1):69–96.
4. Eichenberger AS, Proietti S, Wicky S, Frascarolo P, Suter M, Spahn DR, Magnusson L. Morbid obesity and postoperative pulmonary atelectasis: an underestimated problem. Anesth Analgesia. 2002;95(6):1788.
5. Damia G, Mascheroni D, Croci M, Tarenzi L. Perioperative changes in functional residual capacity in morbidly obese patients. Br J Anaesth. 1988;60(5):574.

6. Pelosi P, Croci M, Ravagnan I, Tredici S, Pedoto A, Lissoni A, Gattinoni L. The effects of body mass on lung volumes, respiratory mechanics, and gas exchange during general anesthesia. Anesth Analgesia. 1998;87(3):654.
7. Hedenstierna G, Santesson J, Norlander O. Airway closure and distribution of inspired gas in the extremely obese, breathing spontaneously and during anaesthesia with intermittent positive pressure ventilation. Acta Anaesthesiol Scand. 2010;20(4):334–42.
8. Patel SR. The complex relationship between weight and sleep apnoea. Thorax 2015.
9. Young T, Palta M, Dempsey J, Skatrud J, Weber S, Badr S. The occurrence of sleep-disordered breathing among middle-aged adults. N Engl J Med. 1993;328(17):1230–5.
10. Kakkar RK, Berry RB. Positive airway pressure treatment for obstructive sleep apnea. Chest. 2007;132(3):1057–72.
11. Freedman N. Treatment of obstructive sleep apnea: choosing the best positive Airway pressure device. Sleep Med Clin. 2017;12(4):529–42.
12. Gross JBAJ. Practice guidelines for the perioperative management of patients with obstructive sleep apnea an updated report by the American Society of Anesthesiologists Task Force on Perioperative Management of patients with obstructive. Anesthesiology. 2014;120:268–86.
13. Chung F, Memtsoudis SG, Ramachandran SK, Nagappa M, Opperer M, Cozowicz C, Patrawala S, Lam D, Kumar A, Joshi GP, et al. Society of Anesthesia and Sleep Medicine Guidelines on Preoperative Screening and Assessment of adult patients with obstructive sleep apnea. Anesth Analgesia. 2016;123(2):452–73.
14. Wells GA, Shea B, O'Connell D, Peterson J, Welch V, Losos M, Tugwell P. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. 2000.
15. by Julian PT, Higgins JS, Matthew J, Page JAC, Sterne. Revised Cochrane risk-of-bias tool for randomized trials (RoB 2). 2019.
16. (RevMan) RM. In., Version 5.4 The Cochrane Collaboration edn; 2020.
17. Evidence-Based. Medicine Assistant Platform [www.ebm-helper.cn.].
18. Huang Qiao WY. Development and introduction of the evidence-based Medicine Research Assistant Online platform. Chin J Evidence-Based Med 2022(12):1483–8.
19. Peker Kizilöz, Tavlan A, Topal A, Erol A, Kiliçaslan A, Otelcioğlu Ş. A comparison of the effects of postoperative CPAP and nasal oxygen use on arterial blood gas in laparoscopic cholecystectomy performed in obese patients: a prospective, randomized cinical trial. Turkiye Klinikleri J Med Sci. 2012;32(3):726–32.
20. Alexandropoulou AN, Louis K, Papakonstantinou A, Tzirogiannis K, Stamataki E, Roussos C, Alchanatis M, Gratziou C, Vagiakis E, Roditis K. The influence of biphasic positive airway pressure vs. sham biphasic positive airway pressure on pulmonary function in morbidly obese patients after bariatric surgery. Anaesthesiol Intensive Ther. 2019;51(2):88–95.
21. Bai Y, Xu Z, Chandrashekar M, St Jacques PJ, Liang Y, Jiang Y, Kla K. Comparison of a simplified nasal continuous positive airways pressure device with nasal cannula in obese patients undergoing colonoscopy during deep sedation: a randomised clinical trial. Eur J Anaesthesiol. 2019;36(9):633–40.
22. Baltieri L, Santos LA, Rasera I, Montebelo MI, Pazzianotto-Forti EM. Use of positive pressure in the bariatric surgery and effects on pulmonary function and prevalence of atelectasis: randomized and blinded clinical trial. Arquivos brasileiros de cirurgia digestiva [Brazilian Archives Dig Surgery]. 2014;27(Suppl 1Suppl 1):26–30.
23. de Raaff CAL, Kalff MC, Coblijn UK, de Vries CEE, de Vries N, Bonjer HJ, van Wagensveld BA. Influence of continuous positive airway pressure on postoperative leakage in bariatric surgery. Surg Obes Relat Dis. 2017;14(2):186–90.
24. Ebeo CT, Benotti PN, Byrd RP Jr, Elmaghraby Z, Lui J. The effect of bi-level positive airway pressure on postoperative pulmonary function following gastric surgery for obesity. Respir Med. 2002;96(9):672–6.
25. Edmark L, Östberg E, Scheer H, Wallquist W, Hedenstierna G, Zetterström H. Preserved oxygenation in obese patients receiving protective ventilation during laparoscopic surgery: a randomized controlled study. Acta Anaesthesiol Scand. 2016;60(1):26–35.
26. El-Sayed KM, Tawfeek MM. Perioperative ventilatory strategies for improving arterial oxygenation and respiratory mechanics in morbidly obese patients undergoing laparoscopic bariatric surgery. Egypt J Anaesth. 2012;28(1):9–15.
27. Gaszynski T, Tokarz A, Piotrowski D, Machala W. Boussignac CPAP in the postoperative period in morbidly obese patients. Obes Surg. 2007;17(4):452–6.
28. Guimarães J, Pinho D, Nunes CS, Cavaleiro CS, Machado HS. Effect of Boussignac continuous positive airway pressure ventilation on Pao2 and Pao2/Fio2 ratio immediately after extubation in morbidly obese patients undergoing bariatric surgery: a randomized controlled trial. J Clin Anesth. 2016;34:562–70.
29. Harbut P, Gozdzik W, Stjernfält E, Marsk R, Hesselvik JF. Continuous positive airway pressure/pressure support pre-oxygenation of morbidly obese patients. Acta Anaesthesiol Scand. 2014;58(6):675–80.
30. Hewidy AA, Suliman LA, El Hefnawy E, Hassan AA. Immediate continuous positive airway pressure (CPAP) therapy after sleeve gastrectomy. Egypt J Chest Dis Tuberculosis. 2016;65(3):701–6.
31. Javanainen MH, Scheinin T, Mustonen H, Leivonen M. Do changes in Perioperative and Postoperative Treatment Protocol Influence the frequency of Pulmonary complications? A retrospective analysis of four different bariatric groups. Obes Surg. 2016;27(1):64–9.
32. Jensen C, Tejirian T, Lewis C, Yadegar J, Dutson E, Mehran A. Postoperative CPAP and BiPAP use can be safely omitted after laparoscopic Roux-en-Y gastric bypass. Surg Obes Relat Dis. 2008;4(4):512–4.
33. Joris JL, Sottiaux TM, Chiche JD, Desaive CJ, Lamy ML. Effect of bi-level positive airway pressure (BiPAP) nasal ventilation on the postoperative pulmonary restrictive syndrome in obese patients undergoing gastroplasty. Chest. 1997;111(3):665–70.
34. Kong WT, Chopra S, Kopf M, Morales C, Khan S, Zuccala K, Choi L, Chronakos J. Perioperative risks of untreated obstructive sleep apnea in the bariatric surgery patient: a retrospective study. Obes Surg. 2016;26(12):2886–90.
35. Meng L. Postoperative nausea and vomiting with application of postoperative continuous positive airway pressure after laparoscopic gastric bypass. Obes Surg. 2010;20(7):876–80.
36. Meurgey JH, Brown R, Woroszyl-Chrusciel A, Steier J. Peri-operative treatment of sleep-disordered breathing and outcomes in bariatric patients. J Thorac Dis. 2017;10(Suppl 1):S144–52.
37. Munaf M, Rajeswari C, Rajaram M, Balachander H. A study on the effect of intraoperative continuous positive airway pressure (CPAP) on the postoperative pulmonary function in overweight patients undergoing lower limb, lower abdominal or vaginal surgeries under spinal anesthesia. Adv Respir Med. 2020;88(3):176–82.
38. Proczko MA, Stepaniak PS, de Quelerij M, van der Lely FH, Smulders JF, Kaska L, Soliman Hamad MA. STOP-Bang and the effect on patient outcome and length of hospital stay when patients are not using continuous positive airway pressure. J Anesth. 2014;28(6):891–7.
39. Ramirez A, Lalor PF, Szomstein S, Rosenthal RJ. Continuous positive airway pressure in immediate postoperative period after laparoscopic Roux-en-Y gastric bypass: is it safe? Surg Obes Relat Dis. 2009;5(5):544–6.
40. Sériès F, Genest C, Martin M, Boutin I, Marceau S, Bussières J, Minville C. CPAP is not needed in every sleep apnea patient awaiting bariatric surgery. Obes Surg. 2021;31(5):2161–7.
41. Sériès F, Martin M, Boutin I, Marceau S, Bussières J, Minville C. Does every obese sleep apnea patients need CPAP treatment before bariatric surgery: results of a validation study. Can J Respiratory Crit Care Sleep Med. 2020;4(4):266–71.
42. Wong DT, Adly E, Ip HYV, Thapar S, Maxted GR, Chung FF. A comparison between the Boussignaccontinuous positive airway pressure mask and the venturi mask in terms of improvement in the PaO2/F1O2ratio in morbidly obese patients undergoing bariatric surgery: a randomized controlled trial. Can J Anesth. 2011;58(6):532–9.
43. De Jong A, Wrigge H, Hedenstierna G, Gattinoni L, Chiumello D, Frat J-P, Ball L, Schetz M, Pickkers P, Jaber S. How to ventilate obese patients in the ICU. Intensive Care Med. 2020;46:2423–35.
44. Li X, Liu H, Wang J, Ni Z-L, Liu Z-X, Jiao J-L, Han Y, Cao J-L. Individualized positive end-expiratory pressure on postoperative atelectasis in patients with obesity: a randomized controlled clinical trial. Anesthesiology. 2023;139(3):262–73.
45. Ferreyra GP, Baussano I, Squadrone V, Richiardi L, Marchiaro G, Del Sorbo L, Mascia L, Merletti F, Ranieri VM. Continuous positive airway pressure for treatment of respiratory complications after abdominal surgery: a systematic review and meta-analysis. Ann Surg. 2008;247(4):617–26.
46. Hui S, Fowler AJ, Cashmore RMJ, Fisher TJ, Schlautmann J, Body S, Lan-Pak-Kee V, Webb M, Kyriakides M, Ng JY, et al. Routine postoperative noninvasive respiratory support and pneumonia after elective surgery: a systematic review and meta-analysis of randomised trials. Br J Anaesth. 2022;128(2):363–74.
47. Huerta S, DeShields S, Shpiner R, Li Z, Liu C, Sawicki M, Arteaga J, Livingston E. Safety and efficacy of postoperative continuous positive Airway pressure to prevent Pulmonary complications after Roux-en-Y gastric bypass. J Gastrointest Surgery: Official J Soc Surg Aliment Tract. 2002;6:354–8.

48. Chung F, Nagappa M, Singh M, Mokhlesi B. CPAP in the perioperative setting. Chest. 2016;149(2):586–97.
49. Faintuch J, Souza S, Valezi A, Sant'Anna A, Gama-Rodrigues J. Pulmonary function and aerobic capacity in asymptomatic bariatric candidates with very severe morbid obesity. 2004:181–6.
50. Alpert MA. Cardiovascular and pulmonary complications of obesity: an overview. Am J Med Sci. 2001;321(4):213–4.
51. Gibson G. Obesity, respiratory function and breathlessness. Thorax. 2000;55(Suppl 1):S41.
52. Koenig SM. Pulmonary complications of obesity. Am J Med Sci. 2001;321(4):249–79.
53. Lazarus R, Gore CJ, Booth M, Owen N. Effects of body composition and fat distribution on ventilatory function in adults. Am J Clin Nutr. 1998;68(1):35–41.
54. Kelly TM, Jensen RL, Elliott G, Crapo RO. Maximum respiratory pressures in morbidly obese subjects. Respiration. 1988;54(2):73–7.
55. Sprung JWD, Falcone T, Warner DO, Hubmayr RD, Hammel J. The impact of morbid obesity, pneumoperitoneum, and posture on respiratory system mechanics and oxygenation during laparoscopy. Anesth Analg 2002(94):1345–50.
56. Bazurro S, Ball L, Pelosi P. Perioperative management of obese patient. Curr Opin Crit Care. 2018;24(6):560–7.

Publisher's Note