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Effect of high body mass index on postoperative pulmonary complications: a retrospective study

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Abstract

Background Postoperative pulmonary complications (PPCs) are associated with perioperative mortality and morbidity. Obesity physiologically affects respiratory function and thus could be a risk factor for PPCs. The aim of this study was to clarify the effect of high body mass index (BMI) and other factors on the development of PPCs and the perioperative course.

Methods This study retrospectively analyzed patients admitted to the intensive care unit (ICU) after undergoing elective upper abdominal surgery at our hospital between December 2015 and December 2018. The primary endpoint was the effect of BMI on the development of PPCs, and the secondary endpoints were the effect of BMI on length of ICU stay, ICU readmission, length of hospital stay, and death within 30 days of surgery.

Results A total of 231 patients were included in this study, 27 of whom had PPCs. BMI was not significantly associated with the development of PPCs. BMI was not significantly associated with length of ICU stay or ICU readmission, whereas higher BMI was significantly associated with shorter hospital stays. The only death within 30 days of surgery occurred in a patient who developed PPCs and died while in the ICU.

Conclusions We retrospectively investigated the effect of BMI on the development of PPCs, length of ICU stay, and ICU readmission in patients who underwent upper abdominal surgery. BMI was not significantly associated with the development of PPCs, length of ICU stay, or ICU readmission.

Keywords Postoperative pulmonary complications, Body mass index, Retrospective study, Overweight, Obese

Background

Postoperative pulmonary complications (PPCs) are associated with perioperative mortality and morbidity, with a reported incidence of 5.8% after open surgery (Yang et al. 2015). Because PPCs require the highest medical costs and longest hospital stay among postoperative complications, it is important to predict risk factors for PPCs in advance and to take measures to prevent such complications (Oto 2018).

Obesity results in reduced functional residual capacity and is a significant risk factor for atelectasis (Lagier et al. 2022). Obesity is also a major risk factor for sleep apnea syndrome (SAS). Thus, it could be a risk factor for PPCs. However, the question of whether obesity is a risk factor for PPCs remains controversial, with some studies showing an association between obesity and PPCs (Covarrubias et al. 2021; Lio et al. 2019) but

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others showing no such association (Zhang et al. 2020; Smetana et al. 2006).

The definition of obesity differs from country to country. The World Health Organization (WHO) defines obesity as body mass index (BMI) ≥ 30, while in Japan, for example, it is defined as BMI ≥ 25 (Yasushi and Hideki 2013). Rather than comparing groups based on well-known thresholds for obesity, the objective of this study was to retrospectively investigate the effect of high BMI on the development of PPCs and the perioperative course.

Methods

This single-center retrospective study was approved by the Institutional Review Board (approval number H2019-099). This study included patients scheduled to be admitted to the intensive care unit (ICU) after elective upper abdominal surgery between December 2015 and December 2018 who had BMI of 22 (the normal reference value) or higher and were aged ≥ 20 years.

Patients who met any the following criteria were excluded: patients who underwent any intrathoracic or airway/lung procedure during surgery, liver transplant recipients, patients with intraoperative blood loss ≥ 3000 ml or hemorrhagic shock, and patients lost to follow-up due to transfer to another hospital or completion of outpatient care within 30 days of surgery.

The following variables were evaluated: age, sex, medical history, smoking history, American Society of Anesthesiologists Physical Status (ASA-PS), operating time, PPCs occurring within 30 days of surgery, requirement for mechanical ventilation, length of ICU stay, ICU readmission within 30 days of surgery, prolonged ICU stay, death during ICU stay, length of hospital stay, and death within 30 days of surgery. PPCs were defined as the presence of any of the following conditions after surgery in medical records: acute respiratory distress syndrome (ARDS), atelectasis, pneumonia, pulmonary edema, pleural effusion, and respiratory failure.

Data analyzed in this retrospective study were collected from patients' electronic medical records in our hospital. Anesthesiologists routinely evaluate all patients undergoing upper abdominal surgery in our hospital. Those evaluations, operative records, postoperative respiratory status, imaging data, and discharge summaries are stored in the electronic medical record system. The primary endpoint was the effect of BMI on the development of PPCs, and the secondary endpoints were the effect of BMI on length of ICU stay, ICU readmission, length of hospital stay, and death within 30 days after surgery.

Statistical analyses used included binomial logistic regression analysis, linear regression analysis, and chi-square test, with a significance level of 5%.

Results

This study included 231 patients with mean BMI of 25.0 ± 2.5. Of these, 134 were of normal weight (BMI 22–24.9), 98 were overweight (BMI 25–29.9), 6 were class I obese (BMI 30–34.9), and 2 were class II obese (BMI 35–39.9). PPCs occurred in 27 of the 231 patients and included pneumonia ($n = 8$), pleural effusion ($n = 8$), atelectasis ($n = 5$), aspiration pneumonia ($n = 4$), pulmonary congestion ($n = 1$), and ARDS ($n = 1$; Fig. 1).

Of the 27 patients with PPCs, 9 (33%) required additional unscheduled ICU management, including ICU readmission ($n = 5$) and prolonged ICU stay ($n = 4$), and 5 (19%) required mechanical ventilation, including noninvasive positive pressure ventilation ($n = 1$), reintubation ($n = 3$), and tracheostomy ($n = 1$). Operating time was significantly longer in patients with PPCs. There were no patients with a history of SAS or asthma (Table 1).

Primary endpoint

Binomial logistic regression analysis was performed with development of PCCs as the dependent variable. The results showed no significant association between BMI and the development of PPCs (Table 2).

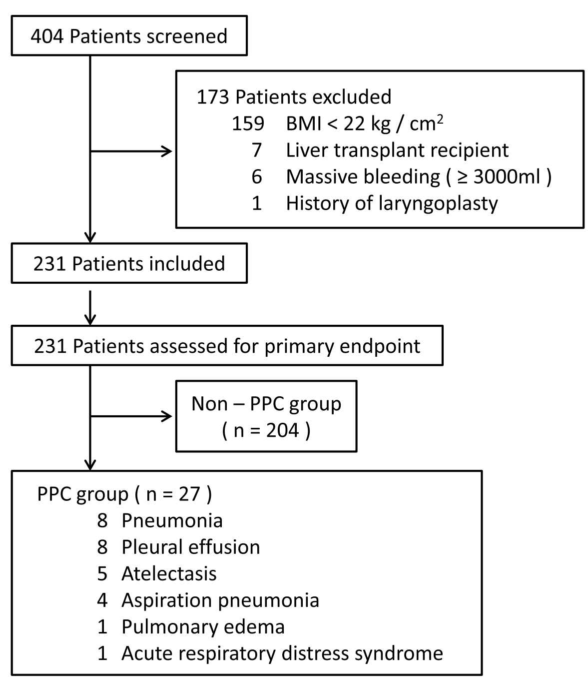

Fig. 1 Flowchart of patient selection

Table 1 Characteristics of patients and surgery

	PPC group (*n* = 27)	non – PPC group (*n* = 204)	*P* value
Age (year)	72.3 ± 10.0	68.8 ± 9.9	0.090
Male (*n*, %)	22 / 5, 81%	143 / 61, 70%	0.177
BMI (kg/m^2)	25.1 ± 3.1	25.0 ± 2.4	0.855
ASA - PS (I/II/III) (*n*)	2 / 17 / 8	21 / 139 / 44	0.337
Surgical time (h)	8.7 ± 3.4	7.1 ± 2.9	0.009
Smoking habit (*n*, %)	19, 70.8%	129, 63.2%	0.470
COPD (*n*, %)	2, 7.4%	7, 3.4%	0.318
SAS (*n*, %)	0, 0%	10, 4.9%	0.001
Asthma (*n*, %)	0, 0%	6, 2.9%	0.369

Data are presented as the mean ± standard deviation or the number of patients and percentage

PPC Postoperative pulmonary complication, *BMI* Body mass index, *ASA-PS* American Society of Anesthesiologist Physical Status, *COPD* Chronic obstructive pulmonary disease, *SAS* Sleep apnea syndrome

Secondary endpoints

Linear regression analysis was performed with length of ICU stay, ICU readmission, and length of hospital stay as dependent variables. Because there was only 1 death within 30 days of surgery, this variable was not included in the statistical analysis.

BMI was not significantly associated with length of ICU stay (Table 3) or ICU readmission (Table 4), whereas higher BMI was significantly associated with shorter hospital stays (Table 5).

The only death within 30 days of surgery occurred in a patient who developed PPCs and died while in the ICU (Table 6).

Other variables

Operating time was significantly associated with the development of PPCs (Table 2). Requirement for mechanical ventilation was significantly associated with length of ICU stay (Table 3). Development of PPC was significantly associated with ICU readmission (Table 4). Longer operating time and ICU readmission were associated with longer hospital stays (Table 5).

Discussion

Several clinical studies have investigated whether high BMI increases PPCs (Covarrubias et al. 2021; Lio et al. 2019; Zhang et al. 2020; Smetana et al. 2006). Covarrubias et al. (Covarrubias et al. 2021) performed a multivariate analysis in patients who underwent open surgery for trauma and found that patients with BMI > 35 had a higher incidence of PPCs and those with BMI > 40 had a higher incidence of PPCs and higher mortality. Lio et al.

Table 2 Adjusted odds ratios and 95% confidence intervals for the occurrence of postoperative pulmonary complication

	Univariate analysis		Multivariate analysis	
	Adjusted odds Ratio (95% CI)	***P* value**	**Adjusted odds Ratio (95% CI)**	***P* value**
BMI (kg/m^2)	1.015 (0.865–1.192)	0.854	1.068 (0.883–1.291)	0.498
Age (year)	1.040 (0.994–1.088)	0.091	1.045 (0.992–1.101)	0.872
Female	0.533 (0.193–1.472)	0.225	0.590 (0.290–1.664)	0.319
ASA – PS	1.426 (0.691–2.941)	0.337	0.590 (0.209–1.663)	0.388
Surgical time (h)	1.190 (1.040–1.361)	0.011	1.209 (1.054–1.387)	0.007
Smoking habit	1.381 (0.576–3.308)	0.469	1.186 (0.369–3.818)	0.775

CI Confidence interval, *BMI* Body mass index, *ASA-PS* American Society of Anesthesiologist Physical Status

Table 3 Odds ratios and 95% confidence intervals for length of ICU stays

	Univariate analysis		Multivariate analysis	
	Odds ratio (95% CI)	***P* value**	**Odds ratio (95% CI)**	***P* value**
BMI (kg/m^2)	-0.028 (-0.178–0.121)	0.709	-0.076 (-0.205–0.053)	0.249
ASA – PS	0.139 (-0.519–0.797)	0.677	-0.247 (-0.834–0.340)	0.408
Surgical time (h)	-0.029 (-0.151–0.093)	0.644	-0.079 (-0.177–0.034)	0.184
PPC	1.827 (0.714–2.941)	0.001	0.147 (-0.945–1.239)	0.791
Requirement for mechanical ventilation	9.698 (7.525–11.870)	< 0.001	9.698 (7.525–11.870)	< 0.001
ICU readmission (≤ 30 days)	4.377 (2.673–6.082)	< 0.001	0.896 (-0.974–2.765)	0.374

CI Confidence interval, *BMI* Body mass index, *ASA-PS* American Society of Anesthesiologist Physical Status, *PPC* Postoperative pulmonary complication

Table 4 Adjusted odds ratios and 95% confidence intervals for ICU readmission within 30 days

	Univariate analysis		Multivariate analysis	
	Adjusted odds ratio (95% CI)	***P* value**	**Adjusted odds ratio (95% CI)**	***P* value**
BMI (kg/m^2)	1.052 (0.830–1.335)	0.674	1.046 (0.794–1.377)	0.751
ASA – PS	1.803 (0.575–5.652)	0.312	1.925 (0.553–6.704)	0.304
Surgical time (h)	1.226 (0.995–1.510)	0.056	1.148 (0.931–1.417)	0.198
Smoking habit	1.324 (0.333–5.263)	0.690	1.211 (0.286–5.121)	0.795
PPC	9.045 (2.427–33.708)	0.001	9.045 (2.427–33.708)	0.001

CI Confidence interval, *BMI* Body mass index, *ASA-PS* American Society of Anesthesiologist Physical Status, *PPC* Postoperative pulmonary complication

Table 5 Odds ratios and 95% confidence intervals for length of hospital stays

	Univariate analysis		Multivariate analysis	
	Odds ratio (95% CI)	***P* value**	**Odds ratio (95% CI)**	***P* value**
BMI (kg/m^2)	-1.486 (-2.933- -0.039)	0.044	-1.371 (-2.674- -0.068)	0.039
ASA – PS	0.231 (-6.205–6.668)	0.944	3.983 (-1.902–9.869)	0.184
Surgical time (h)	3.738 (2.647–4.829)	< 0.001	3.480 (2.405–4.555)	< 0.001
Smoking habit	0.991 (-6.473–8.454)	0.794	-2.072 (-8.998–4.854)	0.556
PPC	15.630 (4.681–26.579)	0.005	6.391 (-3.981–16.764)	0.226
ICU readmission (≤ 30 days)	30.545 (13.424–47.667)	0.001	24.404 (8.595–40.214)	0.003

CI Confidence interval, *BMI* Body mass index, *ASA-PS* American Society of Anesthesiologist Physical Status, *PPC* Postoperative pulmonary complication

Table 6 Comparison of postoperative prognosis in PPC group and non – PPC group

	PPC group (*n* = 27)	**non – PPC group (*n* = 204)**	***P* value**
Length of ICU stays (days)	3.9 ± 8.1	2.1 ± 0.5	0.250
Prolong of ICU stays (*n*, %)	4, 14.8%	11, 5.4%	0.02
Length of prolong of ICU stays (days)	2.3 ± 1.5	1.4 ± 0.7	0.175
ICU readmission (≤ 30 days) (*n*, %)	5, 18.9%	5, 2.5%	< 0.001
Length of hospital stays (days)	47.8 ± 37.4	32.2 ± 25.5	0.044
ICU mortality (≤ 30 days) (*n*, %)	1, 0.4%	0	0.006
Hospital mortality (≤ 30 days) (*n*, %)	1, 0.4%	0	0.006

Data are presented as the mean ± standard deviation or the number of patients and percentage

PPC Postoperative pulmonary complication

(Lio et al. 2019) investigated the effect of BMI on postoperative outcomes after emergency surgery for acute aortic dissection in obese patients with BMI > 30 versus non-obese patients with BMI < 30 using propensity score matching. They found higher mortality and higher incidence of low cardiac output syndrome and PPCs in the obese group.

While those studies suggested an association between BMI and PPCs, other studies have not found this association. In a systematic review and meta-analysis of the effect of BMI on the outcome of cervical spinal fusion, Zhang et al. (Zhang et al. 2020) found that higher BMI was associated with longer hospital stays, higher mortality, and higher incidence of cardiovascular complications, but found no significant difference in the incidence of PPCs between the normal and high BMI groups. Smetana et al. (Smetana et al. 2006) conducted a systematic review on PPCs and identified age, ASA-PS, chronic heart failure, chronic obstructive pulmonary disease (COPD), and smoking, but not obesity, as patient-related risk factors for PPCs. Thus, the question of whether BMI is associated with PPCs remains controversial.

The present study included only patients who underwent upper abdominal surgery, which is theoretically more likely to cause PPCs, but no significant association was found between high BMI and the development of PPCs. There are three possible reasons for this.

First, this study included a small proportion of obese patients as defined by the WHO criteria. Based on the WHO criteria, which defines BMI $\geq$ 25 as overweight and BMI $\geq$ 30 as obese, this study only included 8 obese patients out of 231 patients, and most of the patients were of normal weight or overweight. This may be due to a relatively small percentage of individuals with BMI $\geq$ 30 in the Japanese adult population. Given that no previous reports have shown increased incidence of PPCs in patients with the overweight range of BMI, it is possible that the lower BMI compared with previous studies resulted in the absence of a significant association between BMI and the incidence of PPCs.

The second possible reason is that the introduction of early postoperative mobilization has recently increased. Our hospital has also introduced early postoperative mobilization, and the patients who underwent upper abdominal surgery in this study also started walking exercises the next morning after surgery whenever possible. We had hypothesized that obese patients would be more prone to atelectasis and more likely to have PPCs. However, it is possible that early postoperative mobilization prevented the increased incidence of PPCs due to obesity.

The third possible reason is a lack of statistical power of this study. Except for operating time, none of the known risk factors for PPCs evaluated in this study was significantly associated with the development of PPCs, suggesting a lack of statistical power. In the pre-study sample size calculation, we estimated the incidence of PPCs after non-thoracic surgery to be 40%, based on previous reports (Rock and Rich 2003; Takahiro 2012); however, the actual incidence of PPCs in this study was 12%, about one-third of the estimate, indicating that theoretically about 3 times as many patients were needed. For these reasons, the results of this study should be interpreted with caution.

Notably, higher BMI was significantly associated with shorter ICU stays. The reason for this is not clear, but it may be due to Type I statistical error or the so-called "obesity paradox," a phenomenon in which a higher BMI is associated with improved prognosis in some patient groups, even though overweight and obesity are generally considered risk factors for various diseases. The mechanism of the obesity paradox is not well understood, and various explanations have been proposed. Excess body weight may increase metabolic reserve and thereby counteract the adverse effects of acute injury (Abawi et al. 2017). Moreover, adipose tissue is known to produce soluble tumor necrosis factor receptor (sTNFR) (Mohamed-Ali et al. 1999), and therefore increased sTNFR production in overweight or obese patients may serve as a protective buffer against the negative effects of increased TNF (Abawi et al. 2017). Furthermore, although BMI considers body height and weight, it does not measure the percentage of body fat, the type of fat, the location of fat in the body, or the degree of metabolic abnormalities caused by fat (Abawi et al. 2017), and thus may not accurately reflect the degree of obesity.

Although not included in the study endpoints, operating time was significantly associated with the development of PPCs. This is probably because operating time reflects the extent and invasiveness of surgery and thus is related to the occurrence of PPCs. Although the present study was about BMI, a patient-related risk factor, surgery-related risk factors may have greater relevance.

In the present study, the development of PPCs was associated with longer ICU stay, mechanical ventilation, and ICU readmission, suggesting that the development of PPCs affects patient outcomes. This also implies that further investigation of the onset of PPCs is important for improving the perioperative management of patients.

Conclusions

We investigated the effect of BMI on the development of PPCs, length of ICU stay, and ICU readmission in patients who underwent upper abdominal surgery, which is theoretically more likely to cause PPCs, but found no significant association. The interpretation of the results should take into account that the study had a small proportion of obese patients as defined by the WHO criteria and a possible lack of statistical power.

Abbreviations

ARDS	Acute respiratory distress syndrome
ASA-PS	American Society of Anesthesiologists physical status
BMI	Body mass index
COPD	Chronic obstructive pulmonary disease
ICU	Intensive care unit
PPC	Postoperative pulmonary complication
SAS	Sleep apnea syndrome
sTNFR	Soluble tumor necrosis factor receptor
WHO	World Health Organization

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Authors' contributions

All authors contributed to the study conception and design. KS analyzed and interpreted the patient data and was a major contributor in writing the manuscript. HW, YK, SM, KO, TM, KH and MM supervised this study. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study was approved by the Institutional Review Board of Yamaguchi University Hospital (approval number H2019-099). All data were anonymized and the requirement for informed consent was waived due to the study design.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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