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Original Article

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Severe Obesity and Prolonged Postoperative Mechanical Ventilation in Elderly Vascular Surgery Patients

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Abstract

Background: Severe obesity, defined as body mass index (BMI) ≥ 40 kg/m^2 is increasingly prevalent in elderly surgical patients. Although older age is associated with prolonged postoperative mechanical ventilation (PPMV), the contribution of obesity to this complication in the elderly has not been explored. We investigated the association of severe obesity with the PPMV and the role of severe obesity on mortality risk in patients requiring PPMV.

Methods: We assembled a retrospective cohort of patients ≥ 65 years who underwent inpatient surgical procedures and were either severely obese or normal weight (BMI 18.6 - 24.9 kg/m^2 (National Surgical Quality Improvement Program (NSQIP) 2015 - 2018). PPMV was defined as requirement of postoperative mechanical ventilation for longer than 48 h following surgery. We examined the association between severe obesity and PPMV, using univariable and multivariable logistic regression.

Results: We studied 34,936 patients who were ≥ 65 years of age. The incidence of PPMV was 2.0% (624/31,700) in normal weight patients and 2.8% (92/3,236) in severely obese patients (odds ratio (OR): 1.46; 95% confidence interval (CI): 1.17 - 1.82, P = 0.001). Multivariable analysis, controlling for confounders, estimated a 56% relative increase in the risk of PPMV in severely obese patients, relative to their normal weight peers (OR: 1.56; 95% CI: 1.22 - 1.99, P = 0.001). In normal weight patients, the risk of mortality was multiplied by 23 times in patients who required PPMV (39.6% vs. 2.64%; OR: 23.10; 95% CI: 18.96 - 28.16; P < 0.001). In severely obese patients, PPMV multiplied the risk of mortality by 25 times (30.4% vs. 1.6%; OR: 25.26, 95% CI: 13.44 - 47.50; P < 0.001).

Conclusions: Severe obesity increased the odds of PPMV. Although the incidence of PPMV was low, its requirement conferred up to 25 times greater risk of postoperative mortality, underscoring the need for perioperative mitigation strategies to minimize PPMV risk in elderly patients undergoing vascular surgery.

Keywords: Severe obesity; Mechanical ventilation; Older patient

Introduction

Increasing numbers of adults 65 years or older are undergoing surgery, and many of these patients are obese [1, 2]. A notable epidemiologic phenomenon in recent times is the rapid growth of the elderly population and the increasing prevalence of obesity in this population [3]. Obesity is closely linked with several chronic diseases, including diabetes mellitus, hypertension, dyslipidemia, coronary artery disease, and congestive cardiac failure [4]. Additionally, obesity is an independent risk factor for all-cause mortality and is often considered a major risk factor for poor surgical outcome [5-9].

Another important risk factor for postoperative morbidity and mortality is prolonged postoperative mechanical ventilation (PPMV). Although mechanical ventilation is a lifesaving intervention in the setting of respiratory failure, its prolonged requirement is associated with serious complications that may include ventilator-associated pneumonia, ventilator-induced lung injury, prolonged length of hospital stay, and mortality [10-13]. Also, patients who require PPMV pose logistical and financial challenges to critical care services [14-16]. Given the challenges associated with PPMV, several investigators have attempted to identify perioperative mitigation strategies to minimize the risk of PPMV [17].

Obesity may be an important risk factor for PPMV because it has profound effects on respiratory physiology ranging from the mechanical load of central adiposity on the chest wall with resultant respiratory muscle deconditioning, to diminished lung volumes and capacity as well as increased ventilation-perfusion mismatch [18]. In addition, increasing age is an independent risk factor for PPMV in many studies [2, 19, 20]. This higher risk is explained by age-related physiologic changes in the respiratory and cardiovascular systems, sarcopenia, and preferential central distribution of fat in the elderly [3, 19]. Furthermore, older patients tend to have multiple perioperative comorbidities, thus explaining their distinctively higher risk for PPMV [20].

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The combination of obesity with advanced age would appear to create a clinical "risk stacking" scenario whereby obesity or increasing age would synergistically increase postoperative morbidity including PPMV. However, the association of obesity with postoperative morbidity and mortality is non-linear [21]. Indeed an "obesity paradox" (lower mortality and complication rates) is commonly described [22]. While obesity may protect against postoperative morbidity and mortality, treating the obese population like a homogeneous group is problematic. For example, one can speculate that the risk profile for mildly obese patients will be distinct from those of patients with severe obesity. Despite this potential variability in risk profiles, many investigators have tended analyze data on obese patients as one homogeneous group. To date, very little is known about the effect of severe obesity on PPMV in elderly surgical patients. Recent data among intensive care unit (ICU) patients indicated that while extreme obesity was protective against mortality, it was associated with longer days of mechanical ventilation [23]. Comparable data in an elderly surgical population are unavailable. Therefore, the objectives of this study were, to investigate the association of severe obesity with the requirement of PPMV and to explore the role of severe obesity on mortality risk in patients requiring PPMV.

Materials and Methods

We used the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) Participant User File. The NSQIP is an ongoing quality improvement initiative that aims to produce semiannual risk-adjusted 30-day outcomes of major surgical procedures in both inpatient and outpatient settings. The methodology for collecting these data, including their accuracy and reproducibility, has been detailed in previous publications and briefly reviewed here [24-26]. NSQIP-trained clinical nurse specialists collect and review the veracity of these data using a standardized format and following strict definitions. These data include over 300 perioperative variables, including demographic characteristics, surgical profile, and 30-day postoperative morbidity and mortality outcomes. To ensure data quality, the NSQIP has implemented various quality insurance activities, including the audit of selected sites, regular training, and annual certification of surgical clinical reviewers [25].

We queried a retrospective cohort of patients ≥ 65 years of age who underwent an inpatient surgical procedure between 2015 and 2018 and were either severely obese, defined as a body mass index (BMI) ≥ 40 kg/m^2, or normal weight, defined as a BMI between 18.6 and 24.9 kg/m^2 [27]. We excluded patients who required mechanical ventilation during the 48-h preceding surgery (coded as ventilator-dependent in the database) because these have high baseline risks of PPMV. We also excluded patients who died within 48 h of surgery.

Our outcome of interest was PPMV, defined as requirement for postoperative mechanical ventilation for longer than 48 h following surgery (PPMV was coded as a binary variable: yes, no).

Prolonged ventilation is defined by ACS-NSQIP as being dependent on endotracheal tube, nasotracheal tube, or tracheostomy tube for more than 48 h postoperatively. Postoperative ventilator days were cumulative, which is consistent with previous approach in the literature [12]. Secondary outcome measures included a comparison of 30-day in-hospital mortality rates according to the requirement for PPMV. Finally, we evaluated hospital length of stay (LOS) as a dichotomous variable (prolonged LOS yes/no). LOS was considered prolonged if the patient was not discharged home after 9 days (value of the 75th percentile for the entire study population).

The Institutional Review Board approval was obtained. The study was conducted in compliance with the ethical standards of the responsible institution on human subjects as well as with the Helsinki Declaration.

Statistical analysis

We calculated basic descriptive statistics, including medians (interquartile range (IQR)) for non-normal quantitative variables and frequency (row percentages) for categorical variables. We examined the association between PPMV and severe obesity, using univariable and multivariable logistic regression. We adjusted the analysis for baseline covariates that were included *a priori* based on our hypothesis on the confounding of the association between BMI and the requirement for PPMV. These covariates included gender (female vs. male), BMI (continuous), current smoking status (within 1 year of surgery), emergent case status (yes vs. no), American Society of Anesthesiologists (ASA) physical classification (≥ 3 vs. < 3), diabetes (noninsulin-dependent or insulin-dependent diabetes mellitus: yes vs. no), dyspnea (at rest or moderate exertion: yes vs. no), functional health status within 30 days of surgery (dependent vs. independent), history of chronic heart failure within 30 days of surgery (yes vs. no), history of chronic obstructive pulmonary disease within 30 days of surgery (yes vs. no), hypertension (yes vs. no), bleeding disorder (yes vs. no), corticosteroid use for a chronic condition (yes vs. no), and operating time (in minutes). All reported P values were two-sided, and a P value of 0.05 was significant. Data analysis was carried out with version 15 (StataCorp).

Results

We studied 34,936 patients, ≥ 65 years of age, who underwent vascular surgery in 2015 (n = 8,813, 25.2%), 2016 (n = 9,193, 26.3%), 2017 (n = 9,176, 26.3%), and 2018 (n = 7,754, 22.2%). Table 1 details the baseline demographic and clinical characteristics of the patients stratified according to obesity status. Overall, 39.9% (n = 13,938) were females, and 72.0% (n = 25,137) were White. The majority (86.8%) of the patients were admitted from home. Out of the 34,936 patients included in our sample, 3,236 (9.3%) were severely obese.

Severely obese patients were overrepresented among females (48.9% vs. 39.0%). Patients with severe obesity were more likely to have ASA ≥ 3 (98.4% vs. 96.2%), diabetes (54.6% vs. 25.7%), dyspnea (23.1% vs. 12.4%), congestive

Table 1. Characteristics of the Study Population

Characteristics	Normal weight, BMI ≤ 25 kg/m^2, n (%)	Severe obesity, BMI > 40 kg/m^2, n (%)	Overall, n (%)	Standardized difference in proportion
Study population	31,700 (90.7)	3,236 (9.3)	34,936 (100.0)	
Age (years)				
65 - 74	14,676 (46.3)	2,302 (71.1)	16,978 (48.6)	0.52
75 - 84	12,066 (38.1)	846 (26.1)	12,912 (37.0)	0.26
≥ 85	4,958 (15.6)	88 (2.7)	5,046 (14.4)	0.46
Race				
White	22,688 (71.6)	2,449 (75.7)	25,137 (72.0)	0.09
African American	3,466 (10.9)	373 (11.5)	3,839 (11.0)	0.02
Other	1,031 (3.3)	29 (0.9)	1,060 (3.0)	0.17
Unknown	4,515 (14.2)	385 (11.9)	4,900 (14.0)	0.07
Female sex	12,355 (39.0)	1,583 (48.9)	13,938 (39.9)	0.20
Smoking within one year of surgery	10,611 (33.5)	462 (14.3)	11,073 (31.7)	0.46
Emergency case	2,908 (9.2)	277 (8.6)	3,185 (9.1)	0.02
ASA ≥ 3	30,356 (96.2)	3,171 (98.4)	33,527 (96.4)	0.13
Diabetes	8,138 (25.7)	1,768 (54.6)	9,906 (28.4)	0.62
On dialysis prior to surgery	1,762 (5.6)	213 (6.6)	1,975 (5.7)	0.04
Dyspnea	3,934 (12.4)	749 (23.1)	4,683 (13.4)	0.28
Functional dependency	3,502 (11.1)	332 (10.3)	3,834 (11.0)	0.03
CHF 30 days before surgery	1,145 (3.6)	198 (6.1)	1,343 (3.8)	0.12
History of severe COPD	5,102 (16.1)	560 (17.3)	5,662 (16.2)	0.03
Hypertension requiring medication	25,236 (79.6)	2,889 (89.3)	28,125 (80.5)	0.27
Steroid use for chronic condition	1,575 (5.0)	134 (4.1)	1,709 (4.9)	0.04
Transfusion 72 h before surgery	826 (2.6)	73 (2.3)	899 (2.6)	0.02
Ascites	64 (0.2)	3 (0.1)	67 (0.2)	0.03
Acute renal failure	343 (1.1)	59 (1.8)	402 (1.2)	0.06
Operating time	119 (79 - 182)	115 (78 - 174)	118 (79 - 181)	0.03
Transfer status				
Acute care inpatient	1,186 (3.7)	135 (4.2)	1,321 (3.8)	0.02
From home	27,482 (86.7)	2,826 (87.4)	30,308 (86.8)	0.02
Nursing home/chronic care	1,358 (4.3)	112 (3.5)	1,470 (4.2)	0.04
Outside emergency room	1,445 (4.6)	147 (4.5)	1,592 (4.6)	0.00
Other	209 (0.7)	14 (0.4)	223 (0.6)	0.03
Year of operation				
2015	8,057 (25.4)	756 (23.4)	8,813 (25.2)	0.05
2016	8,296 (26.2)	897 (27.7)	9,193 (26.3)	0.03
2017	8,330 (26.3)	846 (26.1)	9,176 (26.3)	0.00
2018	7,017 (22.1)	737 (22.8)	7,754 (22.2)	0.02

N: number; BMI: body mass index; CHF: congestive heart failure; COPD: chronic obstructive pulmonary disease; ASA: American Society of Anesthesiology.

heart failure 30 days before surgery (6.1% vs. 3.6%), history of severe chronic obstructive pulmonary disease (17.3% vs. 16.1%), hypertension requiring medication (89.3% vs. 79.6%). However, patients with severe obesity were less likely to be ≥ 85 years of age at the time of surgery (2.7% vs. 15.6%) and less likely to have a history of smoking within 1 year of surgery (14.3% vs. 33.5%).

The incidence of PPMV was 2.0% (624/31,700) in pa-

Table 2. Severe Obesity and PPMV

Outcome measures	Obesity status	Number of events, n (%)[a]	Unadjusted analysis		Adjusted analysis[b]	
			OR (95% CI)	P value	OR (95% CI)	P value
Requirement for PPMV	Normal weight, BMI ≤ 25 kg/m^2	624/31,700 (2.0)				
	Severe obesity, BMI > 40 kg/m^2	92/3,236 (2.8)	1.46 (1.17 - 1.82)	0.001	1.56 (1.22 - 1.99)	0.001
Extended length of stay	Normal weight, BMI ≤ 25 kg/m^2	8,073 (25.5)				
	Severe obesity, BMI > 40 kg/m^2	875 (27.0)	1.08 (1.00 - 1.18)	0.051	0.95 (0.86 - 1.04)	0.254

[a]Percentages are for rows. [b]Analyses were adjusted for gender, body mass index, current smoking status, emergent case status, American Society of Anesthesiologists physical classification, diabetes (noninsulin-dependent or insulin-dependent diabetes mellitus), dyspnea (at rest or moderate exertion), functional health status within 30 days of surgery, history of chronic heart failure within 30 days of surgery, history of chronic obstructive pulmonary disease within 30 days of surgery, hypertension, bleeding disorder, corticosteroid use for a chronic condition, and operating time. N: number of events; OR: odds ratio; CI: confidence interval; BMI: body mass index; PPMV: prolonged postoperative mechanical ventilation.

tients with normal weight and 2.8% (92/3,236) in patients with severe obesity (odds ratio (OR): 1.46; 95% confidence interval (CI): 1.17 - 1.82, P = 0.001). Multivariable analysis, controlling for various potential confounder estimated a 56% relative increase in PPMV risk in severely obese patients, relative to their normal weight peers (OR: 1.56; 95% CI: 1.22 - 1.99, P = 0.001) (Table 2).

We defined extended LOS as a value longer equal to the 75th percentile for the sample (9 days). The univariable analysis showed that severely obese patients were more likely to have an extended LOS, although the relationship was not statistically significant (27.0% vs. 25.5%, OR: 1.08; 95% CI: 1.00 - 1.18, P = 0.05) (Table 2).

Requirement of PPMV was strongly associated with mortality, more so in severely obese patients. Among the normal weight patients, the risk of mortality was multiplied by 24 times in patients who required PPMV (39.6% vs. 2.64%; OR: 24.20; 95% CI: 20.30 - 28.83; P < 0.001). In severely obese patients, the effect size was larger, PPMV multiplied the risk of mortality by 27 times (30.4% vs. 1.6%; OR: 27.07, 95% CI: 16.02 - 45.75; P < 0.001). Multivariable analyses, controlling for baseline covariates did not change these results substantially (Table 3).

Discussion

We examined the association of severe obesity with the risk of PPMV and mortality associated with PPMV in a large cohort of elderly patients (age ≥ 65 years) who underwent inpatient vascular surgery procedures. The central finding of this study is that severe obesity increased the risk of PPMV in the elderly vascular surgery population. Furthermore, although the overall incidence of PPMV was low, its requirement resulted in a risk of mortality that was 27 times higher than patients not requiring PPMV. These data demonstrate the potential impact of severe obesity on outcomes following surgical procedures in patients ≥ 65 years of age.

A large proportion of elderly surgical patients can resume and maintain spontaneous ventilation after surgery and do not require PPMV. In most cases, PPMV indicates the occurrence of a severe complication, which may be organ-specific or systemic [28]. Several investigators have described factors associated with PPMV following surgery, but data specific to the elderly surgical patients are limited [17, 29-40]. To our knowledge, there has been no previous attempt to explore the contribution of severe obesity to PPMV in the elderly population. The rising prevalence of obese elderly surgical patients makes it imperative that risk factors for PPMV in this group be identified and that the role of obesity in postoperative complications and mortality risk be characterized. The ability to identify preoperative factors (modifiable or non-modifiable) associated with PPMV in the elderly should help clinicians design perioperative strategies to reduce the need for PPMV or make appropriate preoperative plans for allocation of resources and potential to control the risk of mortality associated with PPMV.

Table 3. PPMV and Mortality

Obesity status	Requirement for PPMV	Mortality/n (%)[a]	Unadjusted analysis		Adjusted analysis[b]	
			OR (95% CI)	P value	OR (95% CI)	P value
Normal weight, BMI ≤ 25 kg/m^2	No	819/31,076 (2.64)				
	Yes	247/624 (39.6)	24.20 (20.30 - 28.83)	< 0.001	23.10 (18.96 - 28.16)	< 0.001
Severe obesity, BMI > 40 kg/m^2	No	50/3,144 (1.6)				
	Yes	28/92 (30.4)	27.07 (16.02 - 45.75)	< 0.001	25.26 (13.44 - 47.5)	< 0.001

[a]Percentages are for rows. [b]Analyses were adjusted for gender, body mass index, current smoking status, emergent case status, American Society of Anesthesiologists physical classification, diabetes (noninsulin-dependent or insulin-dependent diabetes mellitus), dyspnea (at rest or moderate exertion), functional health status within 30 days of surgery, history of chronic heart failure within 30 days of surgery, history of chronic obstructive pulmonary disease within 30 days of surgery , hypertension, bleeding disorder, corticosteroid use for a chronic condition, and operating time. N: number of events; OR: odds ratio; CI: confidence interval; BMI: body mass index; PPMV: prolonged postoperative mechanical ventilation.

Our findings of a higher risk of PPMV in severely obese patients are consistent with previous investigators who demonstrated that obesity is a risk factor for respiratory failure and the need for PPMV following both cardiac surgery and noncardiac surgery [41-43]. Obesity is a risk factor for perturbation of respiratory physiology [18]. It is associated with heightened demand for ventilation, increased work of breathing, decreased lung volumes, and diminished respiratory muscle inefficiency [18]. This respiratory muscle inefficiency is likely to be increased in obese elderly patients because obesity in old age is commonly associated with sarcopenia [19, 44]. Sarcopenic obesity is well described in the elderly and is characterized by progressive loss of muscle bulk and increased fat mass [19, 44]. The increased fat mass is commonly manifested as increased central adiposity, which may further impair respiratory function [19, 44]. However, since we do not have data on the distribution of fat mass in the present study cohort, we cannot directly attribute our observations to central adiposity or sarcopenia.

Most published data indicate that PPMV is associated with increased mortality and morbidity and increased medical costs [11-16]. We found, as did previous investigators, that the death rate in elderly patients requiring PPMV was considerably higher than patients who did not require PPMV [31, 45]. We also provided data for the first time in an elderly surgical cohort, spotlighting the impact of severe obesity on mortality associated with PPMV. Severely obese patients who required PPMV had significantly higher mortality rate despite being significantly younger than patients in the normal BMI category. This group of patients deserve special attention because they constitute the fastest growing category of obese patients. Specific preoperative optimization and risk stratification will allow clinicians to better inform patients and plan appropriate postoperative resource allocation.

The role of obesity as a cofactor in postoperative death in the elderly has not been comprehensively characterized. We previously showed that high BMI was somewhat protective against mortality in elderly postoperative patients resulting in a reverse-J mortality pattern [21]. It appears, from the present investigation, that the protective role of high BMI in postoperative mortality in the elderly is lost or at least attenuated in severely obese patients requiring PPMV. Therefore, caution should be used when describing the association of obesity status with perioperative mortality in the elderly population, since mortality associated with requirement of PPMV is different from all-cause mortality.

Study limitations

Several limitations must be accounted for when interpreting our results. First, our study is retrospective and thus limited by potential unmeasured confounding and measurement biases. In addition, we had no control over the granularity of variables in the dataset. However, we believe that the quality of NSQIP (standard definition of variables and low interrater disagreement) would mitigate these limitations [46]. Furthermore, the retrospective nature of the dataset precluded our analysis from delineating surgeon-specific or hospital-specific factors. We hope that by selecting a homogenous cohort of patients undergoing vascular surgery, we have attenuated the pitfalls from heterogeneity in surgeon and hospital-specific factors. We also recognize that our analyses did not account for intraoperative and postoperative factors that may alter patients' postoperative trajectory. Specifically, the exact site of surgical intervention (thoracic, abdominal, thoracoabdominal, laparoscopic or conventional), is not available in the NSQIP database. To this end, the type of surgical procedure may have influenced the risk stratification in our patient population. Another limitation is the inability to account for within-hospital clustering of PPMV rates because the dataset does not identify participating institutions. However, we cannot think of any reason that our findings are mainly explained by systematic clustering of PPMV requirements. Present analysis is also limited by the fact that granular clinical data about patients' preoperative respiratory status (such as presence of hypercapnic respiratory failure) or degree of respiratory insufficiency were unavailable.

Despite these limitations, this large retrospective cohort study of elderly vascular surgery patients revealed that severe obesity was associated with PPMV. Furthermore, compared to their normal weight peers, severely obese elderly patients who required PPMV had longer postoperative LOS and overall higher post-surgical mortality rates. The severely obese population deserves special attention because of the considerably high mortality in this group among those requiring PPMV.

Conclusions

This retrospective cohort study of elderly vascular surgery patients revealed that severe obesity was associated with prolonged postoperative mechanical ventilation and higher risk of post-surgical mortality.

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None to declare.

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No external funding was received for this work.

Conflict of Interest

The authors declare no competing interests.

Informed Consent

Informed consent was waived.

Author Contributions

Mrs. Khanna helped with the idea conception, study design, critical review of the literature, writing of the manuscript, and revision. Miss. Gbadegesin and Mr. Reline helped with the study design, interpretation of the data and critically reviewed and revised the manuscript. Dr Tobias contributed to the idea conception, oversaw the acquisition and analyses of the data as well as the review of literature, and critically reviewed and revised the manuscript. Dr Nafiu helped with the idea conception, study design, critical review of the literature, data acquisition and analyses, manuscript preparation, and revision.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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