The Effect of Obesity on Outcomes in Mechanically Ventilated Patients in a Medical Intensive Care Unit

Cindy K. Lee^a Eshetu Tefera^b Gene Colice^{c, d}

^aINOVA Loudoun Hospital, Leesburg, Va., and ^bMedStar Health Research Institute, ^cWashington Hospital Center, and ^dThe George Washington University School of Medicine, Washington, D.C., USA

Key Words

Obesity · Mechanical ventilation · Intensive care unit outcomes

Abstract

Background: The effect of obesity on outcomes in critically ill patients requiring invasive mechanical ventilation in a medical intensive care unit (ICU) is uncertain. **Objectives:** This study was intended to further explore the relationship between outcomes and obesity in patients admitted to a medical ICU who required invasive mechanical ventilation. **Methods:** All adult patients admitted to the medical ICU at Washington Hospital Center requiring intubation and invasive mechanical ventilation for at least 24 h between January 1 and December 31, 2009, were retrospectively studied. Patients were categorized as nonobese (BMI <30) and obese (BMI ≥30). The primary outcome measure was 30-day mortality following intubation. Secondary outcomes included ICU length of stay (LOS), hospital LOS and duration of mechanical ventilation. **Results:** There were 504 eligible patients: 306 nonobese and 198 (39%) obese. Obese patients had significantly higher rates of diabetes (43 vs. 30%, $p = 0.004$), hyperlipidemia (32 vs. 24%, $p = 0.04$), asthma (16 vs. 8%, $p = 0.004$) and obstructive sleep apnea requiring con-

tinuous positive airway pressure treatment (12 vs. 1%, $p < 0.001$). Nonobese patients had a significantly higher rate of HIV infection (10 vs. 5%, $p = 0.05$) and malignancy (21 vs. 13%, $p = 0.03$). There were no significant differences in mortality up to 30 days following intubation and secondary outcomes between obese and nonobese patients. Multivariate analysis using logistic regression showed no significant relationship between mortality rate at 30 days following intubation and obesity. Outcomes were similar for the black obese ($n = 153$) and nonobese ($n = 228$) patients and the obese ($n = 85$) and very obese ($n = 113$) patients. **Conclusions:** Obesity did not influence outcomes in critically ill patients requiring invasive mechanical ventilation in a medical ICU. Black obese patients had similar outcomes to black nonobese patients, and very obese patients also had similar outcomes to obese patients.

© 2014 S. Karger AG, Basel

Introduction

Obesity is a US and global epidemic [1, 2]. The age-adjusted obesity prevalence in American men and women is about 35% [2]. Obesity is a serious health concern because it is associated with comorbid illnesses, such as

diabetes, liver disease, hypertension, hyperlipidemia, coronary artery disease and obstructive sleep apnea [3]. Obese people have an excess age-adjusted mortality [4–8]. Obesity causes abnormal pulmonary and cardiac function. Obese patients have deranged lung and chest wall mechanics, a decreased functional residual capacity with increased airway closure during tidal breathing [9, 10] and an increased risk for asthma [11, 12]. Obese patients also have increased circulating blood volume and cardiac output with increased left ventricular (LV) size and mass [13]. They also have an increased right ventricular (RV) mass and RV stroke volume, but a lower RV ejection fraction after adjustment for LV size [14]. These findings suggest that obesity might lead to worse outcomes in critical illness, especially in obese patients requiring mechanical ventilation.

The relationship between obesity and intensive care unit (ICU) outcomes is unclear. In a meta-analysis of 22 studies, Hogue et al. [15] found that ICU mortality, ICU length of stay (LOS) and hospital LOS were not affected by obesity. However, Oliveros and Villamor [16], in a meta-analysis involving 23 studies, found a trend for a reduced ICU mortality rate, but an increased ICU LOS in obese patients. In a meta-analysis of 14 studies, Akinnusi et al. [17] found that obesity was associated with increased ICU LOS and duration of mechanical ventilation, but no difference in ICU mortality. Studies subsequent to these meta-analyses have also provided contradictory results. In a secondary analysis of data from a multicenter international observational study on nutrition, Martino et al. [18] found no differences in mortality rates, but longer ICU LOS and duration of mechanical ventilation in obese patients. Dossett et al. [19] analyzed data from an international study of critically injured adults and also found that obese patients had a longer ICU LOS, but no difference in ICU mortality. Anzueto et al. [20] performed a secondary analysis of patients requiring mechanical ventilation and found that obesity did not affect outcomes. Others found that obesity was not associated with either a prolonged ICU LOS or a difference in ICU mortality [21, 22].

This study was intended to further explore the relationship between outcomes and obesity in patients admitted to a medical ICU who required mechanical ventilation. The primary hypothesis was that obese patients requiring mechanical ventilation in the medical ICU would have worse outcomes than nonobese patients. In addition, secondary hypotheses were that black obese patients and very obese patients would have especially poor outcomes.

Methods

Study Population

The medical records of all patients admitted to the medical ICU at Washington Hospital Center (WHC), a 926-bed tertiary care and urban community hospital, requiring mechanical ventilation for 24 h, between January 1 and December 31, 2009, were retrospectively reviewed. Other inclusion criteria were age ≥ 18 years and documented weight and height in the medical chart within 24 h of ICU admission. Patients with pre-existing limb amputations were excluded because weight measurements could not be used to accurately calculate BMI. A standardized protocol, relying on daily spontaneous breathing trials, was used in the medical ICU to evaluate patients receiving mechanical ventilation for extubation. Because this protocol was not applicable to patients with a prior tracheostomy, these patients were excluded from this study. If patients had more than one admission to the ICU within the study year, only the last readmission to the ICU was included. The Institutional Review Board approved this study (No. 2010-233) and waived the need for informed consent.

Patients were categorized as obese (BMI ≥ 30) and nonobese (BMI < 30). For a secondary analysis, patients with a BMI of ≥ 35 were defined as very obese.

Data Collection

Demographic characteristics (age, gender and race), comorbid illnesses (history of coronary artery disease, congestive heart failure, chronic obstructive pulmonary disease, asthma, diabetes, pulmonary hypertension, hyperlipidemia, human immunodeficiency virus (HIV) infection, malignancy, stroke, obstructive sleep apnea and hypertension), ventilator parameters (tidal volume, plateau pressure and peak inspiratory pressure measured upon initial patient stabilization), complications and clinical outcome data were collected from medical records. The percentage of patients with a plateau pressure > 30 cm H₂O was calculated. Acute Physiology and Chronic Health Evaluation (APACHE) II scores were computed from information obtained on the first day of ICU admission [23].

Outcome Measures and Complications

The primary outcome measure was 30-day mortality following intubation. In-hospital deaths were confirmed by a review of the hospital records. Death status was verified using the Social Security Death Index for patients discharged prior to 30 days following intubation. Secondary outcomes included ICU LOS, hospital LOS and duration of mechanical ventilation. Complications in the ICU documented in the medical record, specifically central line-associated blood stream infection (CLABSI), deep venous thrombosis (DVT) and failed extubation (defined as reintubation within 24 h of extubation), were recorded.

Statistical Analyses

Bivariate analyses were performed using χ^2 tests for categorical variables, *t* tests for continuous variables and Fisher's exact test for categorical variables when all cell frequencies were less than 5. The Wilcoxon rank-sum test was used for skewed continuous variables. Logistic regression was used for multivariate analysis to evaluate the association between obesity and 30-day mortality following intubation, adjusting for confounders. Variables with a *p* value < 0.10 in the bivariate analyses were included in the model. The

Table 1. Demographic characteristics, comorbid illnesses and ventilator parameters

Demographic characteristics	Overall (n = 504)	Nonobese (n = 306)	Obese (n = 198)	p value
Age, years	61.6±16.5	63.0±16.5	59.6±16.2	0.0140
Gender, female	266 (52.8)	148 (48.4)	118 (59.6)	0.0136
APACHE II	24.2±8.1	24.7±8.1	23.4±8.0	0.0768
BMI, kg/m ²	29.5±9.5	23.6±3.9	38.6±8.5	<0.0001
Blacks	381 (75.6)	228 (74.5)	153 (77.3)	0.7268
Comorbid illness				
Hypertension	378 (75.0)	222 (72.6)	156 (78.8)	0.1142
Diabetes	178 (35.3)	93 (30.4)	85 (42.9)	0.0040
Hyperlipidemia	137 (27.2)	73 (23.9)	64 (32.3)	0.0369
Stroke	94 (18.7)	62 (20.3)	32 (16.2)	0.2485
Coronary artery disease	99 (19.6)	67 (21.9)	32 (16.2)	0.1136
Congestive heart failure	116 (23.0)	66 (21.6)	50 (25.3)	0.3373
Malignancy	90 (17.9)	64 (20.9)	26 (13.1)	0.0259
COPD	87 (17.3)	60 (19.6)	27 (13.6)	0.0832
ESRD on hemodialysis	71 (14.1)	43 (14.1)	28 (14.1)	0.9776
Pulmonary hypertension	26 (5.2)	16 (5.2)	10 (5.1)	0.9296
Asthma	56 (11.1)	24 (7.8)	32 (16.2)	0.0037
HIV	40 (7.9)	30 (9.8)	10 (5.1)	0.0538
Obstructive sleep apnea	28 (5.6)	4 (1.3)	24 (12.1)	<0.0001
Ventilator parameters				
Tidal volume, ml	522.6±68.7	507.4±64.6	548.9±67.9	<0.0001
Peak inspiratory pressure, cm H ₂ O	31.5±9.4 (n = 355)	30.1±8.7 (n = 227)	34.1±9.9 (n = 128)	0.0002
Plateau pressure, cm H ₂ O	21.4±7.1 (n = 354)	20.3±6.5 (n = 226)	23.4±7.7 (n = 128)	<0.0001
PaCO ₂ , mm Hg	40.4±12.2	39.4±12.0	41.8±12.4	0.0062

Values are mean ± SD, or number with percentage in parentheses. Bold p values are significant.

Hosmer-Lemeshow c statistic was used to assess goodness of fit. Statistical significance was at a two sided p value ≤0.05.

The sample size would allow us to detect a 12-percentage-point difference given the group numbers. Statistical analyses were performed using Statistical Analysis System software version 9.3 (SAS Institute Inc., Cary, N.C., USA).

Results

Demographic Characteristics, Comorbid Illnesses and Ventilator Parameters

There were 504 eligible patients identified: 306 non-obese and 198 (39%) obese. Obese patients were younger (60 vs. 63 years old, $p = 0.01$) and more likely to be female (60 vs. 48%, $p = 0.01$; table 1). The APACHE II scores were similar for obese and nonobese patients with an overall mean of 24.2 (SD 8.1). Obese patients were significantly more likely to have diabetes (43 vs. 30%, $p = 0.004$), hyperlipidemia (32 vs. 24%, $p = 0.04$), asthma (16

vs. 8%, $p = 0.004$) and obstructive sleep apnea (12 vs. 1%, $p < 0.0001$), but significantly less likely to be infected with HIV (5 vs. 10%, $p = 0.05$). Nonobese patients had a significantly higher comorbid malignancy diagnosis than obese patients (21 vs. 13%, $p = 0.03$). After adjustment for ideal body weight, the obese patients had a significantly higher tidal volume (549 vs. 507 ml, $p < 0.0001$). Obese patients had significantly higher peak inspiratory pressures (34 vs. 30 cm H₂O, $p < 0.0002$) and plateau pressures (23 vs. 20 cm H₂O, $p < 0.0001$) and a significantly greater percentage of obese patients had plateau pressures >30 cm H₂O (13 vs. 6%, $p = 0.04$). The obese patients had significantly higher PaCO₂ levels (42 vs. 39, $p = 0.006$), although the difference was small.

Outcomes and Complications

The bivariate analyses showed no significant differences in clinical outcomes and in ICU complications between obese and nonobese patients (table 2). In logistic regression analysis, variables that remained significantly

Table 2. Outcomes and ICU complications

	Overall (n = 504)	Nonobese (n = 306)	Obese (n = 198)	p value
Outcomes				
Mortality up to 30 days	173 (34.3)	113 (36.9)	60 (30.3)	0.1260
ICU LOS, days	6.2±6.8	5.9±6.5	6.5±7.3	0.5175
Hospital LOS, days	14.8±16.7	14.9±18.0	14.7±14.6	0.9020
Mechanical ventilation, days	5.8±7.4	5.6±6.9	6.1±8.1	0.5877
ICU complications				
CLABSI	7 (1.4)	3 (0.98)	4 (2.0)	0.3300
DVT	20 (4.0)	13 (4.3)	7 (3.5)	0.6888
Failed extubation	31 (6.2)	16 (5.2)	15 (7.6)	0.2841
Values are mean ± SD, or number with percentage in parentheses.				

associated with mortality at 30 days following intubation were a history of malignancy (odds ratio, OR 2.6, 95% CI 1.4–5.0), higher peak inspiratory pressures (OR 1.05, 95% CI 1.02–1.09) and a higher APACHE II score (OR 1.13, 95% CI 1.09–1.17). Obesity did not have an independently significant effect on the outcome (table 3).

Subgroup Analysis (Blacks)

There were 381 black patients: 228 nonobese and 153 (40%) obese. Obese patients in the black subgroup were younger (59 vs. 63 years old, $p = 0.02$) and more often female (60 vs. 48%, $p = 0.02$; table 4). The nonobese black cohort had significantly higher APACHE II scores (25.3 vs. 23.3, $p = 0.03$). Obese black patients more often had a history of diabetes (46 vs. 31%, $p = 0.003$), hyperlipidemia (32 vs. 22%, $p = 0.02$), asthma (18 vs. 10%, $p = 0.02$) and obstructive sleep apnea (11 vs. 1%, $p < 0.0001$). The nonobese black patients were significantly more likely to have a history of malignancy and tended to have HIV infection more often than black obese patients, but the difference was not significant (12 vs. 7%, $p = 0.09$). After adjustment for ideal body weight, black obese patients had higher tidal volumes (524 vs. 508 ml, $p < 0.0001$). Obese black patients had significantly higher plateau pressures (23 vs. 21 cm H₂O, $p = 0.001$), but did not have a significantly higher percentage of patients with plateau pressures >30 cm H₂O compared to nonobese black patients. Nonobese black patients had a significantly higher 30-day mortality rate than the obese black patients (39 vs. 28%, $p = 0.03$), but there was no difference in other outcomes or ICU complications (table 5). Multivariate analysis using logistic regression showed that a history of malignancy (OR 3, 95% CI 1.4–6.7), peak inspiratory pressure (OR 1.05, 95% CI 1.01–1.10) and a higher

Table 3. Multivariate logistic regression model for 30-day mortality adjusting for all significant variables

	OR	95% CI	p value
Diabetes	1.55	0.90–2.67	0.1162
Malignancy	2.63	1.39–5.00	0.0029
Peak inspiratory pressure	1.05	1.02–1.09	0.0053
APACHE II	1.13	1.09–1.17	<0.0001
Obese	0.50	0.21–1.18	0.1134
Age	1.01	0.99–1.03	0.3798
Female vs. Male	0.75	0.41–1.36	0.3384
HLD	0.95	0.53–1.72	0.8706
COPD	0.77	0.37–1.62	0.4929
Asthma	1.37	0.53–3.53	0.5191
HIV	0.94	0.36–2.48	0.8979
Obstructive sleep apnea	1.02	0.31–3.39	0.9759
Tidal volume	0.998	0.994–1.003	0.3995
Plateau pressure	0.98	0.93–1.03	0.4561
PaCO ₂	0.98	0.96–1.01	0.1399

Bold p values are significant. HLD = Hyperlipidemia.

APACHE II score (OR 1.11, 95% CI 1.06–1.16) were independently associated with mortality, but not obesity (table 6).

Subgroup Analysis (Very Obese)

Of the 198 obese patients, 85 (43%) were obese (BMI 32.1 ± 1.4) and 113 (57%) were very obese (BMI 43.5 ± 8.3). The 30-day mortality for the obese and very obese (31.8 vs. 29.2%, respectively) was similar. The ICU LOS (6.6 ± 7.0 vs. 6.4 ± 7.5 days), hospital LOS (13.5 ± 13.2 vs. 15.6 ± 15.6 days) and duration of mechanical ventilation (6.1 ± 8.2 vs. 6.2 ± 8.2 days) were also similar for the obese and very obese patients.

Table 4. Demographic characteristics, comorbid illnesses and ventilator parameters for the black subgroup analysis

Demographic characteristics	Overall (n = 381)	Nonobese (n = 228)	Obese (n = 153)	p value
Age, years	61.6±16.4	63.2±16.2	59.3±16.5	0.0236
Female gender	202 (53.0)	110 (48.3)	92 (60.1)	0.0227
APACHE II	24.5±8.4	25.3±8.4	23.3±8.2	0.0253
BMI, kg/m ²	29.7±10.0	23.4±3.9	39.1±8.9	<0.0001
Comorbid illness				
Hypertension	292 (76.6)	170 (74.6)	122 (79.7)	0.2417
Diabetes	142 (37.3)	71 (31.1)	71 (46.4)	0.0025
Hyperlipidemia	98 (25.7)	49 (21.5)	49 (32.0)	0.0211
Stroke	70 (18.4)	46 (20.2)	24 (15.7)	0.2673
Coronary artery disease	68 (17.9)	43 (18.9)	25 (16.3)	0.5289
Congestive heart failure	94 (24.7)	54 (23.7)	40 (26.1)	0.5851
Malignancy	58 (15.2)	43 (18.9)	15 (9.8)	0.0159
COPD	66 (17.3)	45 (19.7)	21 (13.7)	0.1285
ESRD on hemodialysis	59 (15.5)	34 (14.9)	25 (16.3)	0.7057
Pulmonary hypertension	24 (6.3)	15 (6.6)	9 (5.9)	0.7838
Asthma	49 (12.9)	22 (9.7)	27 (17.7)	0.0223
HIV	37 (9.7)	27 (11.8)	10 (6.5)	0.0864
Obstructive sleep apnea	20 (5.3)	3 (1.3)	17 (11.1)	<0.0001
Ventilator parameters				
Tidal volume, ml	523.8±69.1	507.7±65.7	550.5±66.6	<0.0001
Peak inspiratory pressure, cm H ₂ O	32.1±9.3	30.6±8.7	34.7±9.8	0.0007
Plateau pressure, cm H ₂ O	21.7±6.8	20.7±6.3	23.4±7.2	0.0011
PaCO ₂ , mm Hg	40.4±12.2	39.6±12.5	41.6±11.7	0.0176

Values are mean ± SD, or number with percentage in parentheses. Bold p values are significant.

Table 5. Outcomes and ICU complications for the black subgroup analysis

	Overall (n = 381)	Nonobese (n = 228)	Obese (n = 153)	p value
Outcomes				
Mortality up to 30 days	130 (34.1)	88 (38.6)	42 (27.5)	0.0245
ICU LOS, days	6.2±6.8	5.9±6.2	6.8±7.6	0.3188
Hospital LOS, days	15.4±18.1	15.0±19.6	16.0±15.6	0.2340
Mechanical ventilation, days	6.0±7.5	5.6±6.8	6.6±8.4	0.2445
ICU complications				
CLABSI	7 (1.8)	3 (1.3)	4 (2.6)	0.3548
DVT	15 (3.9)	8 (3.5)	7 (4.6)	0.5998
Failed extubation	19 (5.0)	8 (3.5)	11 (7.2)	0.1057

Values are mean ± SD, or number with percentage in parentheses. Bold p values are significant.

Discussion

In this large, retrospective, single-center study outcomes of obese patients requiring mechanical ventilation admitted to the WHC medical ICU were assessed. Contrary to our hypothesis, there was no difference between

obese and nonobese patients in either the primary or secondary outcomes. In a secondary analysis, the 30-day mortality was higher for the nonobese black population than obese blacks. However, there were no significant differences between the nonobese and obese black populations in other outcomes. In a limited analysis, the very

Table 6. Multivariate logistic regression model for 30-day mortality adjusting for all significant variables for the black subgroup analysis

	OR	95% CI	p value
Diabetes	1.13	0.60–2.13	0.7017
Malignancy	3.0	1.38–6.65	0.0060
Peak inspiratory pressure	1.05	1.01–1.10	0.0204
APACHE II	1.11	1.06–1.16	<0.0001
Obese	0.63	0.32–1.25	0.1865
Plateau pressure	0.99	0.94–1.06	0.9336
Tidal volume	0.997	0.99–1.002	0.2558
HLD	1.18	0.59–2.39	0.6410
Asthma	1.53	0.57–4.15	0.4024
HIV	0.46	0.51–4.18	0.4766
Obstructive sleep apnea	0.75	0.16–3.45	0.7129
PaCO ₂	0.98	0.96–1.01	0.3188

Bold p values are significant. HLD = Hyperlipidemia.

obese did not have worse outcomes than nonobese patients.

Previous studies have provided divergent results on how obesity affects outcome in critical illness, possibly because of heterogeneous patient populations and methods. In meta-analyses addressing this topic, studies have mostly been from mixed medical-surgical ICU populations [15–17]. Data from retrospective analyses of multicenter studies evaluating ICU nutrition, effects of trauma and ICU epidemiology have also used populations from mixed ICUs [18, 19, 21]. Studies including only patients admitted to medical ICUs suffer from methodological limitations. In these studies not all patients required mechanical ventilation [24–28], some lacked appropriate nonobese comparison groups [26, 27], and another used an atypical definition of obesity [28]. O'Brien et al. [22] studied 580 patients requiring mechanical ventilation, including 238 obese patients, admitted to three different medical ICUs. As a novel component of their analysis, they adjusted patient weight based on fluid balance prior to study enrollment. They found no difference in ICU mortality and duration of mechanical ventilation between obese and non-obese patients. Of note, these investigators found a trend for more frequent use of sedative and opioid infusions in the obese patients in this study, suggesting variability in management approaches. The consistent combined results from our study and the study by O'Brien et al. [22], including over 1,000 total and 400 obese patients, reassures us to the robustness of the findings that

obesity does not affect either ICU or hospital mortality in critically ill patients in a medical ICU requiring mechanical ventilation. Interestingly, in studies of patients with acute lung injury [29, 30] and pneumonia [31], the outcomes of obese patients have not been different to nonobese patients.

The subgroup analysis performed in blacks in this study provides insights into a population with little previously available information. Obesity prevalence is higher in blacks than in non-Hispanic whites and Hispanics [2]. Blacks might possibly have different physiologic responses to acute, severe illness [31]. In secondary analyses of large ICU cohorts, blacks had more severe acute physiologic derangements at ICU admission [32, 33]. However, retrospective database analyses suggested that blacks are less likely to develop the systemic inflammatory response syndrome after trauma [34] and are more likely to survive post-traumatic sepsis [35]. In this study, APACHE II scores for blacks were similar to the overall population and ICU mortality was no different for black obese and nonobese patients. The subgroup analysis performed in the very obese, although limited in size, compliments previous work in this area. Subgroup analyses of previous studies suggested that very obese patients might have longer ICU LOS, hospital LOS and duration of mechanical ventilation [15, 21, 25, 26, 29]. These findings might simply reflect the difficulties of providing nursing care for the very obese. This analysis, although limited in numbers, suggests that the very obese did not have outcomes different to the obese.

As expected, there were differences between the obese and nonobese patient groups in comorbid illnesses and physiologic findings. Obesity is a risk factor for the diagnosis of asthma [11] and obstructive sleep apnea. The increased reporting rates of asthma and obstructive sleep apnea in our obese patient population were not associated with more days of mechanical ventilation. Hyperlipidemia and diabetes were more common in the obese population but these did not seem to influence outcomes. It was surprising to find higher rates of malignancy in the nonobese population. Malignancy was found to be significantly related to mortality, but the APACHE II scores were similar for the obese and nonobese. Infection with the HIV virus is common in the economically depressed population served by the WHC. It is unclear, though, why the HIV infection rate was higher in the nonobese group. We and others have found higher peak inspiratory pressures and plateau pressures in obese patients [22]. This might partly be due to reduced lung and chest wall compliance in obese

patients [9, 10], but is also probably due to the higher tidal volumes in the obese. We also found that obese patients had significantly higher PaCO₂ levels compared to nonobese patients despite higher tidal volumes. This observation is probably due to ventilation/perfusion mismatching related to early airway closure in obese patients [10]. The finding of an association between peak inspiratory pressure and 30-day mortality in the multivariate logistic regression model is of uncertain clinical significance. Further work is needed to better understand ventilatory requirements in the obese, critically ill patient.

Hogue et al. [15] found a trend for higher DVT rates in obese critically ill patients, but O'Brien et al. [22] did not find differences in venous thromboembolism rates between obese and nonobese patients. Although obesity is a predisposing factor to DVT, venous thromboembolic disease has not been well studied in critically ill obese patients. Concerns about altered pharmacokinetics leads to exclusion of obese subjects from thromboprophylaxis clinical trials. Practical difficulties with obtaining adequate compression ultrasonography and computed tomographic angiography in obese patients may lead to reduced diagnosis rates of DVT and pulmonary emboli [13]. In this study we did not find an increased rate of clinically documented DVT in obese patients. Obesity has been associated with immunologic changes but the impact of these on CLABSI rates is uncertain [13]. Yaegashi et al. [26] found significantly higher CLABSI rates in morbidly obese ICU patients, but their study did not include an appropriate nonobese comparison group. In our analysis we did not find a difference in CLABSI rates between obese and nonobese patients. Obesity complicates tracheal intubation. Frat et al. [21] reported a higher rate of difficulty with tracheal intubation and postextubation stridor, but their study included only 82 severely obese patients. Our study with a larger sample size found that extubation failure, which includes postextubation stridor, was not different between the obese and nonobese populations.

A strength of this study is the well-defined sedation and extubation protocol which has been used in the WHC medical ICU to manage patients requiring mechanical ventilation for many years. This protocol ensured a consistent approach to managing obese and nonobese patients. Patients in this study had higher APACHE II scores than those included in previous studies of the effect of obesity on ICU outcomes [15, 17, 18]. Differences in ICU outcomes, if they existed, should have been accentuated in a sicker population. The percentage of our medical ICU patients requiring mechanical ventilation who were obese was 39.5%, and more obese patients were female. These findings, similar to those of population-based studies in US adults [2], suggest the results are generalizable. A limitation of this study was that a standard protocol for initiating intubation and mechanical ventilation was not in use during the study period. Although it is possible that obese patients might have been intubated more readily than nonobese patients, APACHE II scores were high in both obese and nonobese patients, indicating acute physiologic derangements in both groups.

In conclusion, in this large, retrospective, single-center study, critically ill obese patients admitted to a medical ICU who required mechanical ventilation did not have worse outcomes than nonobese patients. Subgroup analyses showed that there were no differences in outcomes between black obese and nonobese patients, or between obese and very obese patients.

Acknowledgements

Financial support was provided by an unrestricted grant from the Pulmonary Special Purpose Fund at Washington Hospital Center.

Financial Disclosure and Conflicts of Interest

None of the authors have received personal or financial support from an organization with a financial interest in the subject matter of this manuscript.

References

- 1 WHO Consultation Report: Obesity: preventing and managing the global epidemic. WHO Technical Report Series 894. Geneva, World Health Organization, 2000.
- 2 Flegal KM, Carroll MD, Kit BK, Ogden CL: Prevalence of obesity and trends in the distribution of body mass index among US adults, 1999–2010. *JAMA* 2012;307:491–497.
- 3 Pieracci FM, Barie PS, Pomp A: Critical care of the bariatric patient. *Crit Care Med* 2006; 34:1796–1804.
- 4 Flegal KM, Graubard BI, Williamson DF, et al: Excess deaths associated with underweight, overweight, and obesity. *JAMA* 2005;293: 1861–1867.
- 5 Prospective Studies Collaboration: Body-mass index and cause-specific mortality in 900,000 adults: collaborative analyses of 57 prospective studies. *Lancet* 2009;373:1083–1096.
- 6 Berrington de Gonzalez A, Hartge P, Cerhan JR, et al: Body-mass index and mortality among 1.46 million white adults. *N Engl J Med* 2010;363:2211–2219.

- 7 Boggs DA, Rosenberg L, Cozier YC, et al: General and abdominal obesity and risk of death among black women. *N Engl J Med* 2011;365:901–908.
- 8 Zheng W, McLerran DF, Rolland B, et al: Association between body mass index and risk of death in more than 1 million Asians. *N Engl J Med* 2011;364:719–729.
- 9 Pelosi P, Croci M, Ravagnan I, et al: Total respiratory system, lung, and chest wall mechanics in sedated-paralyzed postoperative morbidly obese patients. *Chest* 1996;109:144–151.
- 10 Salome CM, King GG, Berend N: Physiology of obesity and effects on lung function. *J Appl Physiol* 2010;108:206–211.
- 11 Dixon AE, Holguin F, Sood A, et al: An official American Thoracic Society workshop report: obesity and asthma. *Proc Am Thorac Soc* 2010;7:325–335.
- 12 Skloot G, Schechter C, Desai A, et al: Impaired response to deep inspiration in obesity. *J Appl Physiol* 2011;111:726–734.
- 13 Honiden S, McArdle JR: Obesity in the intensive care unit. *Clin Chest Med* 2009;30:581–599.
- 14 Chahal H, McClelland RL, Tandri H, et al: Obesity and right ventricular structure and function. *Chest* 2012;141:388–395.
- 15 Hogue CW, Stearns JD, Colantuoni E, et al: The impact of obesity on outcomes after critical illness: a meta-analysis. *Intensive Care Med* 2009;35:1152–1170.
- 16 Oliveros H, Villamor E: Obesity and mortality in critically ill adults: a systematic review and meta-analysis. *Obesity* 2008;16:515–521.
- 17 Akinnusi ME, Pineda LA, El Solh AA: Effect of obesity on intensive care morbidity and mortality: a meta-analysis. *Crit Care Med* 2008;36:151–158.
- 18 Martino JL, Stapleton RD, Wang M, et al: Extreme obesity and outcomes in critically ill patients. *Chest* 2011;140:1198–1206.
- 19 Dossett LA, Heffernan D, Lightfoot M, et al: Obesity and pulmonary complications in critically injured adults. *Chest* 2008;134:974–980.
- 20 Anzueto A, Frutos-Vivar F, Esteban A, et al: Influence of body mass index on outcome of the mechanically ventilated patients. *Thorax* 2011;66:66–73.
- 21 Frat JP, Gissot V, Ragot S, et al: Impact of obesity in mechanically ventilated patients: a prospective study. *Intensive Care Med* 2008;34:1991–1998.
- 22 O'Brien JM, Philips GS, Ali NA, et al: The association between body mass index, processes of care, and outcomes from mechanical ventilation: a prospective cohort study. *Crit Care Med* 2012;40:1456–1463.
- 23 Knaus WA, Draper EA, Wagner DP, et al: APACHE II: a severity of disease classification system. *Crit Care Medicine* 1985;13:818–829.
- 24 Ray DE, Matchett SC, Baker K, et al: The effect of body mass index on patient outcomes in a medical ICU. *Chest* 2005;127:2125–2131.
- 25 El-Solh A, Sikka P, Bozkanat E, et al: Morbid obesity in the medical ICU. *Chest* 2001;120:1989–1997.
- 26 Yaegashi M, Jean R, Zuriqat M, et al: Outcome of morbid obesity in the intensive care unit. *J Intensive Care Med* 2005;20:147–154.
- 27 Duarte AG, Justino E, Bigler T, et al: Outcomes of morbidly obese patients requiring mechanical ventilation for acute respiratory failure. *Crit Care Med* 2007;35:732–737.
- 28 Goulenok C, Monchi M, Chiche JD, et al: Influence of overweight on ICU mortality. *Chest* 2004;125:1441–1445.
- 29 Morris AE, Stapleton RD, Rubenfeld GD, et al: The association between body mass index and clinical outcomes in acute lung injury. *Chest* 2007;131:342–348.
- 30 O'Brien JM, Welsh CH, Fish RH, et al: Excess body weight is not independently associated with outcome in mechanically ventilated patients with acute lung injury. *Ann Intern Med* 2004;140:338–345.
- 31 King P, Mortensen EM, Bollinger M, et al: Impact of obesity on outcomes for patients hospitalized with pneumonia. *Eur Respir J* 2013;41:929–934.
- 32 Erickson SE, Vasilevskis EE, Kuzniewicz MW, et al: The effect of race and ethnicity on outcomes among patients in the intensive care unit. *Crit Care Med* 2011;39:429–435.
- 33 Williams JF, Zimmerman JE, Wagner DP, et al: African-American and white patients admitted to the intensive care unit: is there a difference in therapy and outcome? *Crit Care Med* 1995;23:626–636.
- 34 NeSmith EG, Weinrich SP, Andrews JO, et al: Demographic differences in systemic inflammatory response syndrome score after trauma. *Am J Crit Care* 2012;21:35–42.
- 35 Plurad DS, Lustenberger T, Kilday P, et al: The association of race and survival from sepsis after injury. *Am Surg* 2010;76:43–47.