Medical Versus Surgical ICU Obese Patient Outcome: A Propensity-Matched Analysis to Resolve Clinical Trial Controversies

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Objectives: To determine the short- and long-term mortality of obese ICU patients following medical as opposed to surgical admission and the relation between obesity and mortality.

Design: Retrospective analysis of prospectively collected data, using a propensity score–matched analysis of patients with medical or surgical admission.

Setting: One French mixed medical-surgical ICU.

Patients: Critically ill obese patients (body mass index ≥ 30 kg/m^2) and nonobese patients admitted during a 14-year period.

Interventions: None.

Measurements and Main Results: Seven-hundred ninety-one obese patients and 4,644 nonobese patients were included, 338 (43%) and 2,367 (51%) medical and 453 (57%) and 2,277 (49%) surgical obese and nonobese patients, respectively. Mortality was significantly higher in medical than in surgical obese patients in ICU (25% vs 12%; $p < 0.001$) and up to 365 days (36% vs 18%; $p < 0.001$) post ICU admission. One-to-one propensity score matching generated 260 pairs with well-balanced baseline characteristics. After matching on propensity score, mortality was still significantly higher in medical patients both in the ICU (21% vs 13%; $p = 0.03$) and up to 365 days (30% vs 20%; $p = 0.01$) post ICU admission. Obesity was not significantly associated with mortality both in univariate analysis (140 obese patients [15%] in the dead group vs 651 [14%] in the alive group; $p = 0.72$) and multivariate analysis (odds ratio, 1.09 [95% CI, 0.86–1.38]; $p = 0.49$) after adjustment for Simplified Acute Physiology Score II, age, category of admission, history of cardiac disease, and history of respiratory disease.

Conclusions: After careful matching, the data suggest that ICU mortality in obese population was higher in the medical group than in the surgical group and remains significantly higher 365 days post ICU admission.

Key Words: critical care; intensive care unit; mechanical ventilation; obese; obesity

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Obesity has become a worldwide health concern. The prevalence of obese adults in the United States has risen significantly over the last decade to 35% (1). Although obesity contributes to many diseases and is associated with higher all-cause mortality in the general population (2), the relationship between body mass index (BMI) and ICU mortality remains controversial (3–5). To date, approximately

50 published articles evaluated the impact of obesity on the ICU mortality and reported a wide range of mortality rates varying from 0% to 33%. The findings are generally tricky to interpret as a result of heterogeneous studies. Obesity was associated with an increased risk of mortality in some studies and with no or protective effects in others. Furthermore, the relationship between obesity and long term-survival, up to 12 months post ICU discharge, has been examined in only few studies (6–9).

Medical category of admission is a major predictive factor of mortality in critically ill patients, included in severity scores predicting mortality such as Simplified Acute Physiology Score (SAPS) II (10) and corrected Acute Physiology and Chronic Health Evaluation (APACHE) IV (11) scores. In specific populations such as patients with nosocomial pneumonia (12) or elderly patients (13), medical category of admission is also an independent risk factor of mortality. However, no distinction was made between surgical and medical patients through the different studies assessing the prognosis of obese ICU patients. To adjust for potential confounding factors, severity scores predicting ICU mortality were used. Nonetheless, these severity scores designed for ICU patients, such as the SAPS II (10) or APACHE IV (11) scores, were not designed for predicting outcome in the obese population and not validated in this specific population. Severity scores should be customized to fit in the population where they will be used because the population from which the models were derived may be different from a specific population such as obese patients (14, 15).

The main objective of this study was to determine the influence of the admission category (medical vs surgical) on mortality of ICU obese patients before and after performing a one-to-one propensity score–matched analysis of category of admission. We hypothesized that medical (vs surgical) category of admission could be a major predictive factor of mortality in the specific population of obese patients. The secondary objectives were to assess the influence of the admission category on mortality in nonobese patients, the relation between mortality and obesity in the overall population, the performance of the SAPS II score to predict ICU mortality in obese and nonobese population, and to develop a prognostic model for predicting ICU mortality in obese patients.

MATERIALS AND METHODS

Study Design

We conducted a retrospective analysis of prospectively collected data from January 1999 to January 2013 in a 16-bed, mixed medical-surgical adult ICU in a university teaching hospital. We obtained approval from the local scientific and ethics committee of the "Comité d'Organisation et de Gestion de l'Anesthésie Réanimation" of the Montpellier University Hospital, who stated that no informed consent of the patient or next of kin was required because no change in care practices.

Data Collection

Patient body weight and height were measured at the time of ICU admission. In accordance with international standards (16), patients with a BMI greater than or equal to 30 kg/m^2 were defined as obese. All consecutive obese and nonobese patients hospitalized during the study period in our medical-surgical ICU were included in the study. Only the first admission of each obese and nonobese patient was retained for analysis. Patient data were recorded by the ICU's in-house physician and included age, gender, SAPS II (10), ICU admission diagnosis, category of admission (medical or surgical), and comorbidities. Body weight classes were reported according to the World Health Organization (WHO) (16). Additional information are available in the **Supplemental Digital Content 1** (http://links.lww.com/CCM/D181).

Outcome Measures

ICU mortality rates were obtained using hospital electronic patient records. Mortality data at 180 days and 365 days post admission in obese patients were determined via telephone calls to the patients or their families. Secondary outcome evaluation in obese patients was based on the requirement and duration of invasive mechanical ventilation, ICU length of stay, acquired acute renal failure, need of renal replacement therapy, and presence of hospital acquired infections.

Statistical Analysis

Additional information are available in the Supplemental Digital Content 1 (http://links.lww.com/CCM/D181). Mortality was analyzed in the ICU, as well as at 180 and 365 days post admission for obese patients. A Kaplan-Meier analysis was performed in obese patients to determine the survival lifetimes for 365-day survival, and a log-rank test was used to compare the two curves (medical category vs surgical category). Hazard ratios (HRs) of mortality in ICU, at 180 and at 365 days between medical and surgical patients, were obtained by the Cox method.

A first analysis was performed in the obese nonmatched population, aiming to compare medical and surgical patients.

A second analysis was performed after adjustment on confounding factors between medical and surgical obese groups using a propensity score analysis.

A third analysis was performed in the nonobese population, aiming to compare medical and surgical patients, before and after propensity score matching, using the same methodology than in obese patients. Then the mortality rates in medical and surgical patients were compared between obese and nonobese matched populations.

A fourth analysis was done to assess the relation between obesity and mortality, in the overall population. A univariate analysis was first computed. Then an optimal model was built by logistic multivariate analysis.

A fifth analysis was performed to assess the risk factors for ICU mortality in obese population. A univariate analysis was first computed. Then an optimal model was built by logistic multivariate analysis.

A sixth analysis was performed to assess the performance of SAPS II for predicting mortality in obese patients.

The statistical analysis was performed by the medical statistical department of the Montpellier University Hospital with

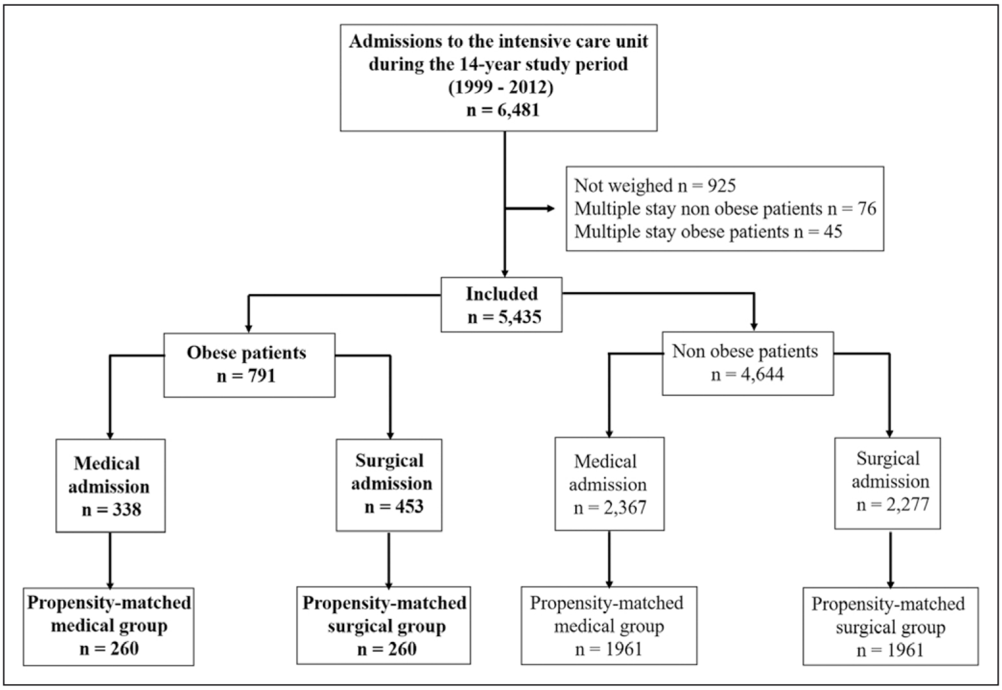

Figure 1. Flow chart of the study.

the help of statistical software (SAS, version 9.3; SAS Institute, Cary, NC), and statistical significance was fixed at the 0.05 level.

RESULTS

Of the 6,481 patients admitted to the ICU during the study period, 996 (15%) were not weighed upon admission and 50 (1%) had already been admitted to the ICU before. Five-thousand four-hundred thirty-five patients were included: 4,644 nonobese patients (85%) and 791 obese patients (15%). Among the obese patients, 338 (43%) had medical and 453 (57%) had surgical indications for ICU admission. Among the nonobese patients, 2,367 (51 %) had medical and 2,277 (49%) had surgical indications for ICU admission. **Figure 1** presents the flow chart of the study.

First Analysis: Obese Nonmatched Population

Table 1 presents the main characteristics of medical and surgical obese patients, before and after matching. Before matching, medical patients had a significantly lower BMI than surgical patients (36 ± 9 vs $38 \pm 10\,kg/m^2$; $p < 0.001$). They were older (62 ± 14 vs 59 ± 14 yr; $p = 0.008$) and had higher SAPS II (44 ± 20 vs 37 ± 16; $p < 0.001$) than surgical patients. In surgical patients, 338 patients (75%) were admitted after elective major surgery and 114 patients (25%) for postoperative complications. Medical patients had significantly higher mortality in ICU (25% vs 12%; $p < 0.001$) and up to 180 (31% vs 16%; $p < 0.001$) and 365 days (36% vs 18%; $p < 0.001$) post ICU admission.

Figure 2*A* shows the Kaplan-Meier curves at 1 year after ICU admission in surgical and medical obese patients before matching. Mortality in ICU, at 180, and at 365 days were significantly higher in the medical category (respectively HR, 2.20 [95% CI, 1.58–3.11]; $p < 0.001$; HR, 2.14 [95% CI, 1.59–2.89); $p < 0.001$; and HR, 2.24 [95% CI, 1.70–2.98]; $p < 0.001$).

Second Analysis: Obese Population After Propensity Score Matching

Using the algorithm described above, we were able to match 260 patients in the surgical group with 260 in the medical group (Fig. 1), after adjusting for propensity score. In surgical patients, 183 patients (70%) were admitted after elective major surgery and 77 patients (30%) for postoperative complications. The variables significantly associated with category of admission and included in the propensity score were SAPS II, cardiac disease, sepsis at admission, mechanical ventilation, pulmonary infection, and BMI. Patients in the surgical and medical groups had mean propensity scores of 0.37 and 0.51, respectively. The *C*-statistic (area under the receiver operating curve) was 0.71 (0.67–0.75).The goodness of fit, assessed with Hosmer and Lemeshow test, was 0.33.

The two groups were comparable after propensity score matching (Table 1). Mortality was significantly higher in medical than in surgical patients in ICU (21% vs 13%; $p = 0.03$) and up to 180 (26% vs 18%; $p = 0.02$) and 365 days (30% vs 20%; $p = 0.01$) post ICU admission (**Table 2**).

Figure 2*B* shows the Kaplan-Meier curves at 1 year after ICU admission in surgical and medical obese matched patients. Mortality in ICU, at 180, and at 365 days were significantly higher in the medical category (respectively HR, 1.61 [95% CI, 1.05–2.47); $p = 0.03$; HR, 1.53 [95% CI, 1.06–2.22]; $p = 0.03$; and HR, 1.57 (95% CI, 1.11–2.23); $p = 0.01$).

Third Analysis: Nonobese Population Analysis

Table 3 presents the main characteristics of medical and surgical nonobese patients, before and after matching. The two groups were comparable after propensity score matching (Table 3). ICU mortality was significantly higher in medical than in surgical patients, both before and after matching (22% vs 12%; $p < 0.001$ and 17% vs 14%; $p = 0.001$, respectively).

After matching, in the medical group, 339 nonobese patients (17%) died, versus 54 obese patients (21%) ($p = 0.17$), and in the surgical group, 266 nonobese patients (14%) died, versus 35 obese patients (13%) ($p = 0.96$).

Fourth Analysis: Relation Between Obesity and Mortality in the Overall Population

Supplemental Table 1 (Supplemental Digital Content 1, http://links.lww.com/CCM/D181) presents the univariate analysis of

TABLE 1. Characteristics of Medical and Surgical Obese Patients in the Unmatched and Propensity-Matched Groups

Patients Characteristics	Unmatched Groups Medical ($n = 338$)	Unmatched Groups Surgical ($n = 453$)	p	Propensity-Matched Groups Medical ($n = 260$)	Propensity-Matched Groups Surgical ($n = 260$)	p
Age (yr), mean ± SD	62 ± 14	59 ± 14	0.008	60 ± 14	61 ± 13	0.22
Male gender, n (%)	193 (57)	258 (57)	0.94	155 (60)	151 (58)	0.69
BMI (kg/m^2)[a], mean ± SD	36 ± 9	38 ± 10	0.001	37 ± 9	37 ± 8	0.14
Obesity grade 1 (30 ≤ BMI < 35), n (%)	196 (58)	217 (48)	0.005	143 (55)	128 (49)	0.19
Obesity grade 2 (35 ≤ BMI < 40), n (%)	71 (21)	102 (23)	0.61	54 (21)	65 (25)	0.25
Obesity grade 3 (BMI ≥ 40), n (%)	71 (21)	133 (29)	0.008	63 (24)	67 (26)	0.69
Simplified Acute Physiology Score II, mean ± SD	44 ± 20	37 ± 16	< 0.001	40 ± 17	41 ± 17	0.65
Current smoker, n (%)	77 (23)	118 (26)	0.29	68 (26)	69 (27)	0.92
Chronic alcoholism, n (%)	49 (14)	64 (14)	0.89	42 (16)	33 (13)	0.26
Systemic arterial hypertension, n (%)	116 (34)	156 (34)	0.97	91 (35)	90 (35)	0.93
Cardiac disease, n (%)	40 (12)	33 (7)	0.03	26 (10)	25 (10)	0.88
Respiratory disease, n (%)	32 (10)	67 (15)	0.03	28 (11)	43 (17)	0.06
Diabetes mellitus, n (%)	68 (20)	85 (19)	0.63	52 (20)	48 (18)	0.66
Chronic renal disease, n (%)	18 (5)	23 (5)	0.88	10 (4)	17 (7)	0.17
Status at admission, n (%)						
Sepsis	96 (28)	121 (27)	0.61	65 (25)	70 (27)	0.62
Pulmonary infection	74 (22)	184 (41)	< 0.001	74 (28)	85 (33)	0.30
Acute renal failure	28 (8)	44 (10)	0.50	22 (9)	28 (11)	0.37
Mechanical ventilation	222 (66)	356 (79)	< 0.001	185 (71)	185 (71)	1.00
Acute respiratory distress syndrome	79 (23)	65 (14)	0.001	59 (23)	44 (17)	0.10

BMI = body mass index.

[a]Exact BMI was available for 790 patients in unmatched groups and 520 patients in matched groups.

mortality in the overall population. Obesity was not significantly associated with mortality (140 obese patients [15%] in the dead group vs 651 [14%] in the alive group; $p = 0.72$). Mortality did not significantly differ across the WHO classification of weight.

After multivariate logistic analysis, main risk factors of mortality were SAPS II, age, category of admission, history of cardiac disease, and history of respiratory disease (**Supplemental Table 2**, Supplemental Digital Content 1, http://links.lww.com/CCM/D181). Obesity was not significantly associated with ICU mortality (odds ratio, 1.09 [95% CI, 0.86–1.38]; $p = 0.49$).

Fifth Analysis: Risk Factors of Mortality in the Matched Obese Population

Supplemental Table 3 (Supplemental Digital Content 1, http://links.lww.com/CCM/D181) presents the univariate analysis of mortality in the matched obese population.

After multivariate logistic analysis, main risk factors of mortality were SAPS II, category of admission, history of cardiac disease, and mechanical ventilation at admission (**Supplemental Table 4**, Supplemental Digital Content 1, http://links.lww.com/CCM/D181).

Sixth Analysis: Performance of SAPS II

Additional data are provided in Supplement Digital Content 1 (http://links.lww.com/CCM/D181).

DISCUSSION

The major findings of this propensity-matched study are that ICU mortality was significantly higher in the medical obese patients than in the surgical obese patients and that this higher mortality rate persisted up to 365 days post ICU admission (Fig. 2). Obesity was not associated with ICU mortality, both in univariate and multivariate analysis. An exploratory multivariate model including SAPS II, category of admission, history of cardiac disease, and mechanical ventilation at admission was developed for prediction of ICU mortality in obese patients.

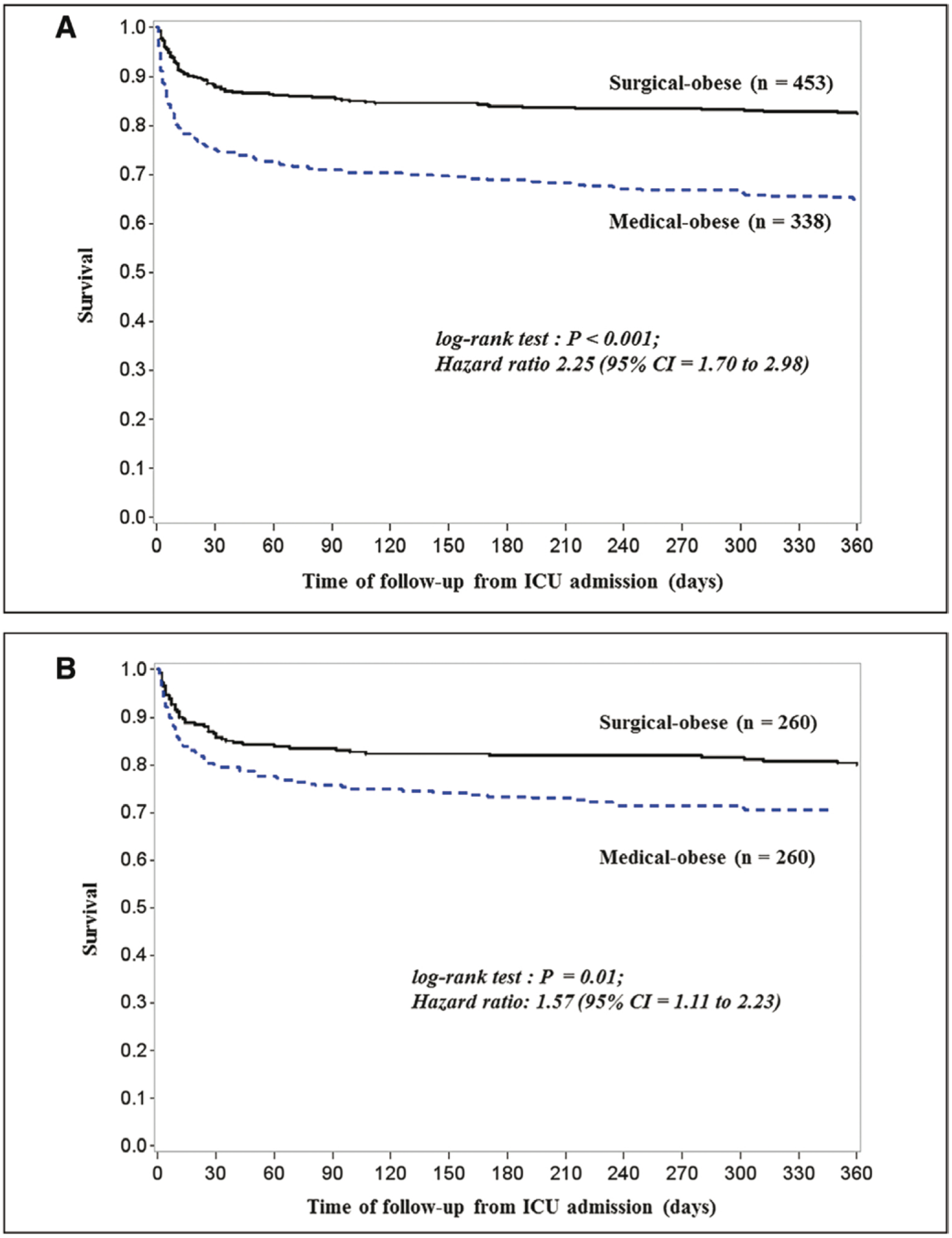

Figure 2. Percentage of survival at 1 yr after ICU admission in surgical and medical obese patients. **A**, Before matching. Mortality of obese medical patients at 365 d after admission was significantly higher than mortality in obese surgical patients (log-rank test: $p < 0.001$; hazard ratio 2.25 [95% CI, 1.70–2.98]). **B**, After matching. Mortality of obese medical patients at 365 d after admission was significantly higher than mortality in obese surgical patients (log-rank test: $p = 0.01$; hazard ratio 1.57 [95% CI, 1.11–2.23]).

In studies assessing influence of obesity on ICU mortality, medical and surgical population were often mixed. Consequently, interpreting the results of these studies, adjusting for severity scores only without specific adjustment for category of admission, is challenging. Some medical population studies have reported that obesity was associated with increased ICU mortality (17, 18). In a mixed medical-surgical cohort, Bercault et al (19) found an obesity-related excess ICU mortality rate. Other studies examining mixed medical and surgical patient populations did not report obesity-related increased ICU mortality (20, 21). In a large Australian prospective study, Peake et al (6) were the first to report that obesity was an independent predictor of survival up to 360 days following ICU admission. These results were confirmed in the general population and in severe sepsis (22–24). Overall, obesity and mortality in critically ill patients were inversely associated in meta-analyses (25–27). However, in the specific population of trauma patients, obesity was associated with a worse prognosis (28), may be because of an increased risk of hypovolemic shock (29). The seemingly contradictory findings published could well be the result of differing study designs, analytical methods, and patient populations (medical, surgical, trauma, and mixed). Additionally, given that diaphragm dysfunction following ICU admission has been associated with a poorer prognosis (30) and that improved diaphragmatic function was recently found in obese rats compared with nonobese rats (31), differences of diaphragmatic function could also be an explanation to the observed differences between medical and surgical obese patients. In the current cohort, after adjusting for SAPS II, age, category of admission, history of cardiac disease, and history of respiratory disease, obesity was not significantly associated with lower or higher mortality. These results were similar to the results found in a recent meta-analysis (32), showing that in sepsis cases, overweight, but not obesity or morbid obesity, was associated with lower mortality. However, in the current study, mortality did not differ across weight classes (from underweight to extreme obesity). One explanation of the similar prognosis of obese patients compared with nonobese patients could be that our mixed medical-surgical ICU is part of an obesity center. The obese patients are not considered at higher risk of worse outcome compared with nonobese patients (33). A lot of critical obese patients are admitted to intermediate

TABLE 2. Outcomes of Medical and Surgical Obese Patients in the Unmatched and Propensity-Matched Groups

Outcomes	Unmatched Groups			Propensity-Matched Groups		
	Medical ($n = 338$)	Surgical ($n = 453$)	p	Medical ($n = 260$)	Surgical ($n = 260$)	p
Nosocomial infection, n (%)	59 (17)	69 (15)	0.40	55 (21)	39 (15)	0.07
Acquired acute renal failure, n (%)	35 (10)	47 (10)	0.99	24 (9)	24 (9)	1.00
Renal replacement therapy, n (%)	50 (15)	54 (12)	0.24	37 (14)	37 (14)	1.00
Duration of mechanical ventilation (d), mean ± SD	6 ± 12	5 ± 12	0.41	7 ± 13	4 ± 9	0.07
ICU length of stay (d), mean ± SD	11 ± 19	11 ± 17	0.44	12 ± 21	10 ± 15	0.40
ICU mortality, n (%)	84 (25)	56 (12)	< 0.001	54 (21)	35 (13)	0.03
Mortality at 6 mo, n (%)	104 (31)	73 (16)	< 0.001	68 (26)	47 (18)	0.02
Mortality at 12 mo, n (%)	121 (36)	82 (18)	< 0.001	78 (30)	53 (20)	0.01

TABLE 3. Characteristics of Medical and Surgical Nonobese Patients in the Unmatched and Propensity-Matched Groups

Patients Characteristics and Outcomes	Unmatched Groups			Propensity-Matched Groups		
	Medical ($n = 2,367$)	Surgical ($n = 2,277$)	p	Medical ($n = 1,961$)	Surgical ($n = 1,961$)	p
Age (yr), mean ± SD	58 ± 17	60 ± 16	< 0.001	59 ± 17	59 ± 16	0.98
Male gender, n (%)	1,554 (66)	1,543 (68)	0.74	1,299 (66)	1,338 (68)	0.18
BMI (kg/m^2)[a], mean ± SD	24 ± 7	24 ± 4	0.78	24 ± 7	24 ± 4	0.89
Underweight (BMI < 18.5), n (%)	171/1,822 (9)	138/1,868 (7)	0.03	141/1,494 (9)	124/1,620 (8)	0.07
Normal weight (18.5 ≤ BMI < 25), n (%)	982/1,822 (54)	980/1,868 (53)	0.38	802/1,494 (54)	843/1,620 (52)	0.36
Overweight (25 ≤ BMI < 30), n (%)	669/1,822 (37)	750/1,868 (40)	0.03	551/1,494 (37)	653/1,620 (40)	0.05
Simplified Acute Physiology Score II, mean ± SD	44 ± 21	38 ± 18	< 0.001	40 ± 19	39 ± 18	0.24
Current smoker, n (%)	506 (21)	458 (20)	0.29	382 (19)	376 (19)	0.81
Chronic alcoholism, n (%)	467 (20)	322 (14)	< 0.001	301 (15)	312 (16)	0.63
Systemic arterial hypertension, n (%)	350 (15)	383 (17)	0.06	301 (15)	299 (15)	0.93
Cardiac disease, n (%)	124 (5)	107 (5)	0.40	88 (5)	95 (5)	0.60
Respiratory disease, n (%)	134 (6)	126 (6)	0.85	103 (5)	102 (5)	0.94
Diabetes mellitus, n (%)	209 (9)	205 (9)	0.84	161 (8)	172 (9)	0.53
Chronic renal disease, n (%)	105 (4)	88 (4)	0.33	81 (4)	75 (4)	0.62
Acute respiratory distress syndrome, n (%)	328 (14)	202 (9)	< 0.001	192 (10)	192 (10)	0.71

BMI = body mass index.

[a]Exact BMI was available for 3,690 patients in unmatched groups and 3,132 in matched groups.

care units. If these obese patients had been admitted to ICU, the rates of mortality of obese ICU population could have been decreased. Furthermore, obese patients are prone to hypoxemia, which could result in a lower Pa_{O_2}/F_{IO_2} compared with normal weight patients despite a similar pulmonary injury. Appropriate ventilatory settings, based on low tidal volume adjusted to ideal body weight and moderate to high levels of positive end-expiratory pressure, could decrease hypoxemia (34) and are part of our standard care, both in medical and in surgical patients (35).

A multivariate model was then performed in obese patients, with the aim to predict ICU mortality in obese patients. SAPS II, age, category of admission, and history of cardiac disease were independently associated with ICU mortality in obese patients. Further studies are needed to determine whether applying this model to an external cohort would improve the effectiveness of the SAPS II in predicting mortality in obese patients.

The following limitations should be considered when assessing the clinical relevance of our results. First, although weight was determined at ICU admission, we cannot exclude the possibility that fluids given prior to admission may have affected the BMI. Second, as this is an observational and not a randomized study, we cannot exclude the possibility of unmeasured confounding. For example, interventions that may have reduced morbidity and mortality such as recruitment maneuvers (36, 37) or intubation protocol (38–42) were not standardized and probably changed over time, as well as implementation of high-flow oxygen therapy (43) or sedation-analgesia protocol (44–46). To decrease the selection bias, we used propensity score matching, which presumably improves the validity of the analysis. However, unmeasured confounding cannot be excluded, such as nutrition status (47) which was not assessed. Third, this was a single-center study, and results may differ in other settings and other populations.

CONCLUSIONS

The current notion that all obese patients have similar ICU outcomes should be reconsidered. We specifically compared medical and surgical critically ill obese patient populations during their ICU stay and up to 365 days following ICU admission. After careful matching, the results demonstrated that the medical category of admission was associated with worse prognosis than the surgical category of admission in obese ICU patients. After adjustment for category of admission, ICU mortality did not differ between obese and nonobese patients.

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