Influence of Overweight on ICU Mortality*

A Prospective Study

Cyril Goulenok, MD; Mehran Monchi, MD; Jean-Daniel Chiche, MD;
Jean-Paul Mira, MD; Jean-François Dhainaut, MD, PhD; and Alain Cariou, MD

Study objective: Overweight patients seem to have a poorer outcome and a higher risk of complications during their stay in the ICU. We conducted a prospective study in order to examine the relationship between body mass index (BMI) and mortality among these patients.

Design: Prospective clinical study.

Setting: A 24-bed medical ICU in a university-affiliated hospital.

Methods: All patients hospitalized in the ICU over a 1-year period were included except those dying or being discharged from the hospital within 24 h of admission. Overweight patients were defined as those having a BMI > 75th percentile of this selected ICU population. Other data collected were demographic and ICU-related data. The Mann-Whitney test was used to compare numeric data between groups (*ie*, obese and nonobese populations). Variables that were significantly associated with ICU mortality by univariate analysis were entered into a multiple logistic regression model, allowing the determination of independent predictors.

Results: Eight hundred thirteen patients were included in the study. The limit of the upper quartile of the BMI was 27. This value was used to separate obese (n = 215) and nonobese (n = 598) groups. Significant differences between obese and nonobese patients were observed in age, length of stay in the ICU, simplified acute physiology score (SAPS) II, and ICU mortality. The observed mortality of obese patients was significantly higher than that predicted by SAPS II (32% vs 18%, respectively; p = 0.001). No difference was observed in frequency of nosocomial infection or duration of mechanical ventilation for mortality in ICU patients. Using a multivariate analysis, the predictive factors of mortality were SAPS II (p < 0.0001) and BMI > 27 (p < 0.01).

Conclusion: This is the first prospective study showing high BMI value as an independent prognostic factor of mortality for ICU patients. The prognostic scoring systems currently in use, which were designed to predict the mortality of ICU patients, do not include BMI or do not consider obesity. These may underestimate, therefore, the risk for the specific population of obese patients. *(CHEST 2004; 125:1441–1445)*

Key words: body mass index; critical illness; mortality; obesity; overweight; prognostic index

Abbreviations: APACHE = acute physiology and chronic health evaluation; BMI = body mass index; LOS = length of stay; SAPS = simplified acute physiology score

Obesity is among the most significant public health problems. There is overwhelming evidence that the prevalence of obesity is increasing worldwide, both in developed and developing countries. Morbid obesity is associated with a greater incidence of a wide spectrum of medical and surgical pathologies. During the last decade, the increase of obesity incidence in the general population has led to a higher number of obese patients being hospitalized in ICUs. However, the direct influence of excessive body weight on ICU mortality remains controversial. Few data are available on morbidity and mortality in obese patients in the medical intensive care setting, but it is widely held that their outcomes are poor.[1,2] Obese patients requiring critical care represent a considerable challenge for intensivists, needing specific adjustment of drug regimens, parameters of mechanical ventilation, and nursing, and are associated with a high risk of ICU complications. Practical considerations like the limited capacity of stretchers or operating tables, or the presence of unadapted

devices for ICU monitoring (*eg*, BP cuffs, pulse oximeter devices, and capnography or monitoring of neuromuscular block) influence the medical care given to this specific population. Outcome assessment and prediction have become popular and essential in both the trauma and critical care settings. Despite this, it is surprising that morbid obesity was not included as a comorbid variable in the development of common ICU prognostic scores such as APACHE (acute physiology and chronic health evaluation) or simplified acute physiology score (SAPS).[3,4]

Obesity is defined by an excess of body fat frequently resulting in a significant impairment of health. The concept of ideal body weight originates in life insurance studies, which established that for a given height and gender a low weight was associated with the lowest mortality rate. The body mass index (BMI) is currently the more accepted index of the relationship between height and weight, and is widely used in clinical and epidemiologic studies.[5,6]

We hypothesized that patients admitted to the ICU with higher BMIs would have higher mortality. Thus, a prospective study was conducted in order to examine the relationship between BMI and mortality among patients in this specific population.

Materials and Methods

Study Location

The study was conducted at a university hospital (1,100 beds) in a 24-bed medical ICU that has approximately 1,000 hospitalizations per year.

Data Collection

We included all patients hospitalized in our medical ICU during a 1-year period from January 1, 1999, to January 1, 2000. The degree of obesity was assessed by the BMI using the following formula: BMI = body weight (kg)/height (m^2). Body weight and size were measured for all patients at the time of ICU admission. We defined *obese patients* as those with a BMI > 75th percentile of this ICU population. Patients who died or were discharged from the ICU within 24 h of admission were excluded because data collection (height and weight) was difficult for patients who died rapidly or was unnecessary for patients hospitalized for < 1 day.

The other collected data were demographic, as follows: age; gender; smoking history; immunodepression (*eg*, hematologic malignancy, metastatic cancer, or AIDS); MacCabe score; and ICU-related data (*ie*, admitting diagnosis, medical or surgical reason for admission, length of stay [LOS] in the ICU, ICU mortality, time and duration of mechanical ventilation, invasive procedures performed [*eg*, urinary or vascular catheter placement, tracheotomy, chest tube placement, and renal replacement therapy]; and presence of nosocomial infections [occurring > 48 h after hospitalization]). SAPS II was calculated for each patient and was used to estimate the predicted mortality.[7]

Statistical Analysis

Continuous data are presented as the median and corresponding 25th and 75th percentiles (*ie*, interquartile range). Dichotomous data are presented as percentages. The χ^2 test or the Fisher exact test was applied for dichotomous and categoric data. The Mann-Whitney test was used to compare numeric data between groups (*ie*, obese and nonobese populations, and survivors and nonsurvivors). Univariate analysis was performed using nonparametric statistical tests. Variables that were significantly associated with ICU mortality by univariate analysis were entered into a multiple logistic regression model, allowing the determination of independent parameters. A two-tailed p value of < 0.05 was considered to be statistically significant. Analyses were performed using a statistical software package (STATA, version 7.0 for Windows; StataCorp; College Station, TX).

Results

Demographic Data

Nine hundred ninety-one patients were hospitalized in the ICU during the study period. One hundred thirty patients were excluded from the study because their LOS in the ICU was < 24 h. Of the 861 remaining patients, complete height and weight data were available in 813 cases (94.4% of the full population). Characteristics of the study population are presented in Table 1. As indicated, the limit of the upper quartile of the BMI was 27. This value was used to separate the obese group (215 patients; 26.4%) and the nonobese group (598 patients; 73.6%).

The 813 admission diagnoses were mapped into nine disease groups (Table 2). There was no significant difference in admission diagnoses between the obese and nonobese groups (data not shown). We registered 77 nosocomial infections that occurred in 49 patients, including 25 infections of the urinary tract, 9 positive blood cultures, 33 cases of pneumonia, and 10 central venous catheter infections. There

Table 1—*Characteristics of the Study Population*

Variables	Values
Patients, No.	813
Age, yr	51 (37–68)
Male gender, %	58
BMI	23 (21–27)
Smoking history	123 (28.7)
SAPS II	33 (21–50)
Mortality	127 (15.6)
ICU LOS, d	4 (2–8)
Mechanical ventilation, %	49
Duration of mechanical ventilation, d	3 (2–8)
Renal replacement therapy	103 (12.7)
Nosocomial infection	49 (6.3)

*Values given as median (interquartile range) or No. (%), unless otherwise indicated.

Disease groups	No. (%)
Pulmonary disease	275 (33.8)
Cardiovascular disease	108 (13.3)
Neurologic disease	103 (12.7)
Infectious disease	92 (11.3)
Renal insufficiency	60 (7.4)
Poisoning	83 (10.2)
Metabolic disorder	31 (3.8)
Digestive disease	21 (2.6)
Other	40 (4.9)

was no significant difference in nosocomial infection incidence between obese and nonobese patients.

For the full population, the median LOS in the ICU was 4 days (interquartile range, 2 to 7 days), the MacCabe score was 1.44 (interquartile range, 1 to 3), and SAPS II was 33 (interquartile range, 21 to 50), leading to a predicted mortality rate of 27%.[7] The observed mortality rate was 16% (127 patients). BMI values were significantly higher among nonsurvivors compared with survivors (26.1 vs 24.2 respectively; p = 0.004).

Obese and nonobese patients were compared using univariate analysis. The results are shown in Table 3. The following significant differences between obese and nonobese patients were observed: age; SAPS II; LOS in the ICU; and ICU mortality rate. Interestingly, the observed mortality rate of obese patients was significantly higher than the predicted mortality rate by SAPS II (32% vs 18%, respectively; p = 0.001). No difference was observed concerning the usual determinants of mortality in

ICU patients (ie, nosocomial infection and duration of mechanical ventilation). Variables significantly associated with mortality in the univariate analysis (ie, LOS in the ICU, age, BMI ≥ 27, and SAPS II) were included in a multiple logistic model in which ICU mortality was the dependent variable. The results are presented in Table 4. Using this multivariate analysis, the independent predictive factors of mortality were SAPS II (p < 0.0001) and BMI ≥ 27 (p < 0.01).

DISCUSSION

This study demonstrates that overweight patients have an increased mortality rate during their ICU hospitalization. To our knowledge, this is the first prospective study demonstrating the independent influence of BMI on mortality in the ICU. Since the Framingham study[5] showed that obese patients have a mortality rate that is 3.9 times greater than a normal weight group, several studies have focused on the mortality of overweight patients in different settings. For medical ICUs, only three studies have explored the influence of BMI on mortality.[2,8,9] One study[8] did not show any excess risk of mortality for BMI values > 85th percentile (without indication of precise BMI). However, missing data (30.2%) were more frequent for extremely ill patients as well as for those who died, probably therefore leading to bias. The second study[2] was retrospective, and showed an increased risk of morbidity and mortality for *morbidly obese patients* (defined as a BMI > 40. By multivariate analysis, multiorgan failure, PaO_2/fraction of inspired oxygen ratio, and depressed left ventricular ejection fraction were independently as-

Table 3—Univariate Analysis Comparing Obese and Nonobese Patients*

Variables	Nonobese Patients (n = 598)	Obese Patients (n = 215)	p Value
Age, yr*	48 (34–65)	58 (47–71)	< 0.001
Weight, kg	64 (56–70)	85 (78–91)	< 0.001
Height, cm	170 (163–175)	166 (160–173)	< 0.001
Male gender, %	41	42	0.73
Smoking history, %	71	70	0.75
Immunodepression,† %	4	7	0.21
Nosocomial infections, %	6	7	0.5
Nosocomial infections for 1,000 d, No.	4.9	4.9	0.48
Mechanical ventilation in ICU, %	59	66	0.054
Duration of mechanical ventilation, d	3 (2–8)	4 (2–9)	0.22
LOS in ICU, d	3 (2–7)	4 (2–8)	0.024
SAPS II	32 (19–48)	36 (27–56)	< 0.001
SAPS II predicted mortality‡	13% (11–15)	18% (15–26)	< 0.001
ICU mortality, %	13	32	< 0.001

*Values given as median (interquartile range), unless otherwise indicated.
†For example, metastatic cancer, hematologic malignancy, immunosuppressive treatment, and AIDS.
‡Values given as mean (95% confidence interval).

Table 4—Multivariate Analysis*

Variables	OR	p Value	95% CI
Age	1.01	0.098	0.99–1.02
LOS in ICU	1.02	0.11	0.99–1.04
SAPS II (for each additional point)	1.08	< 0.0001	1.07–1.10
BMI > 27	1.83	0.017	1.10–2.86

*OR = odds ratio; CI = confidence interval.

sociated with ICU mortality in the extremely obese group. Because missing data were not detected due to the retrospective design, it is difficult to draw a conclusion about the exact influence of BMI on mortality in this study. The third study,[9] recently published, was a retrospective analysis of a large multi-institutional ICU database. The percentage of missing data was high, with 35.6% of patients having incomplete data for height or weight. In accord with ICU practitioners, the authors acknowledged that height and weight data are often estimated rather than measured. Estimation in ICU of these specific data were shown to be significantly inaccurate for individuals observers.[10] They found an increase of LOS only for underweight and severely obese patients, but no increase of mortality. However, when these authors used a cutoff value of 28, there was a significantly higher mortality rate in the group of overweight patients. The prospective design of our study explains the very small number of patients with missing data (5.6%). For posttraumatic patients, the effect of obesity on mortality was examined in several studies[1,11,12] with somewhat different conclusions. There are only limited data on the effect of obesity on the outcome after heart, kidney, or liver transplantation.[13,14] Two recent studies[15,16] have suggested the negative influence of obesity on survival after liver or kidney transplantation.

Based on the current World Health Organization guidelines,[17] *overweight* is defined by a BMI > 25. With this criterion, the prevalence of overweight individuals is 55% for adults in the United States,[18] and the National Health and Nutrition Examination Survey reports[19] that 34.9% of US adults have a BMI > 27.5. The European population is significantly different from the US population. In the general population, patients with a BMI between 20 and 25 are usually considered to be normal, those with a BMI of 25 to 30 are considered to be overweight, those with a BMI of 30 to 35 are considered to be obese, those with a BMI of 35 to 55 are considered to be morbidly obese, and those with a BMI > 55 are considered to be severely overweight.[20] We defined our obese population as those patients with a BMI > 75th percentile of our global population, which

corresponds to 27. This definition is better adapted to the specific ICU population than is the usual definition of obesity. In reference to a recent epidemiologic study,[21] the distribution of our ICU population is similar to the French general population.

Despite evidence that BMI constitutes an independent factor for mortality in the ICU, we cannot single out the reasons for this. There is only a trend showing that obese patients require more mechanical ventilation than nonobese patients (66% vs 59%, respectively; p = 0.054). Surprisingly, the nosocomial infection rate and the duration of mechanical ventilation were not increased in the obese group compared with the nonobese group. Only ICU LOS was significantly higher for patients with a BMI > 27. The monocenter design of our study and the short 1-year study period have certainly reduced the size of the study population. To confirm our results and to identify the independent factors associated with an increased risk of mortality in the obese population, a multicenter study is needed. To perform this study, a prospective design seems essential because of the high percentage of patients with missing weight and height data in retrospective studies using ICU databases.[2,8,9] Height and weight must be measured and not just estimated, as is most frequently done.[10]

There are a lot of associated factors in the treatment of overweight patients in the ICU that were not accounted for. Alterations in pulmonary function (*ie*, decrease of vital capacity, total lung capacity, and functional residual volume with increased airway resistance) have important implications in the treatment of obese patients requiring mechanical ventilation. Choban et al[1] showed that excess mortality in obese patients with blunt trauma related primarily to respiratory failure. Cardiovascular effects include decreased cardiac output, impaired left ventricular contractility, and depressed ejection fraction.[22–24] The risk of deep-vein thrombosis or pulmonary embolus is increased in obese patients.[25] This increase results from prolonged immobilization leading to venous stasis. Future studies should include deep vein thrombosis assessment with systematic ultrasonography of the major veins in this specific population. Obese patients develop protein energy malnutrition in response to metabolic stress despite excess body fat stores and large lean body stores. The metabolic response to severe trauma appears to be different in obese and nonobese subjects, as demonstrated by Jeevanandam et al,[26] who showed that obese trauma patients catabolized more proteins and less fat than nonobese trauma patients. GI disorders are also more common in this population as determined by a combination of increased intraabdominal pressure, and high volume and low pH of gastric

contents, leading to an increased risk of gastroesophageal reflux and a higher risk of aspiration pneumonia.[27] Short neck and loss of anatomic landmarks make vascular access difficult, especially for central venous catheterization. Finally, the distribution, metabolism, protein binding, and clearance of many drugs are altered by the physiologic changes associated with obesity. Subcutaneous routes should be avoided, since absorption is very unreliable. Furthermore, the current guidelines in therapeutic management (eg, for treatment dosages and ventilator settings) may be inappropriate for the obese population. The analysis of all these criteria in a large multicenter study may help us to understand the reasons for the increased mortality.

In conclusion, obesity clearly influences the prognosis of patients hospitalized in the ICU. This is the first prospective study showing high BMI as an independent prognostic factor of mortality for acutely ill patients. Surprisingly, overweight was not taken into consideration by the usual scoring systems such as APACHE (acute physiology and chronic health evaluation) or SAPS II, probably because height and weight are not routinely recorded in ICU. Thus, the usual prognostic scores that are designed to predict the mortality of ICU patients may neglect an important parameter that may lead to an underestimation of mortality in the specific population of obese patients, as reflected by an observed mortality that is higher than the predicted mortality.

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