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ORIGINAL ARTICLE

The impact of body mass index on treatment outcomes among traumatic brain injury patients in intensive care units

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Abstract
Purpose Obesity is a risk factor in treatment outcomes of critically ill patients. This study was conducted to determine the impact of obesity on the likelihood of recovery from traumatic brain injury (TBI) in intensive care unit (ICU) patients.
Methods We carried out a prospective study on 115 head injury patients who were admitted to the ICU of Poursina Hospital, Rasht, in the one-year period between July 2006 and June 2007. Obese patients (body mass index [BMI] $\geq$ 30 kg/m^2) were compared with non-obese patients (BMI $<$ 30 kg/m^2). Demographic information, acute physiology and chronic health evaluation scores, Injury Severity Scores (ISS), Glasgow Coma Scale scores, and ICU mortality incidences were recorded.
Results Obese patients had significantly higher ICU mortality rates compared to non-obese patients ($p = 0.02$). Furthermore, we observed a trend towards a higher ICU mortality rate in obese patients with ISS > 25 ($p = 0.04$). Moreover, obesity was associated with prolonged mechanical ventilation, ICU length of stay (ILOS), and hospital length of stay (HLOS) ($p < 0.001$).
Conclusions Obesity was associated with increased ICU mortality and prolonged dependency on mechanical ventilation, ILOS, and HLOS in patients with TBI. However, further prospective studies with larger sample sizes are needed to substantiate these findings.

Keywords Obesity · Body mass index · ICU · Traumatic brain injury · Mortality · Hospital length of stay · ICU length of stay

Introduction

Obesity is a global concern, with rising levels of obesity in populations around the world. Based on a report from the

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World Health Organization (WHO), over 200 million males and nearly 300 million females around the world are obese [1]. In the US, 55 % of the adult population are overweight, i.e., with BMI > 30 [2]. It has been demonstrated that obesity is a risk factor for higher mortality and morbidity due to acute and chronic medical conditions [3–6]. The potential impact of obesity on patients with various medical conditions, particularly those in the intensive care unit (ICU), remains controversial [7–12]. While many studies have shown increased morbidity and mortality in obese trauma patients [8, 12–17], others have found no difference, or even report lower mortality rates in this patient population [14, 18–22]. Mixed results are also reported in regards to the association between obesity and an increased number of complications after surgery in critically ill obese patients [12, 23–25].

Considering the challenges encountered in the treatment of obese patients when injured, we aimed to conduct a prospective study to examine the impact of obesity on treatment outcomes, measured as ICU mortality, ventilation use, ICU length of stay (ILOS), and hospital length of stay (HLOS), in TBI-ICU patients.

Materials and methods

The study was conducted over a one-year period (July 2006–June 2007) on patients admitted to the Poursina Medical Center ICU, located in Rasht, a city in Guilan Province, in the northern region of Iran. We reviewed the medical histories of all patients who were admitted to the Neuro-ICU. Those who were 20 years or older, and had stayed in the ICU for more than 24 h, were enrolled in the study after obtaining consent, either from the patient or from a family member when the patient was not alert or conscious. Patients with skull fractures and severe chest and abdominal injuries were excluded. BMI was calculated by dividing the patient's weight (in kg) by height (in m^2). Patients were grouped by their calculated BMI into either obese or non-obese. Obese patients were defined as those with a BMI $\geq$ 30 kg/m^2 while non-obese patients had a BMI < 30 kg/m^2. Patient data, including age, gender, height, and weight, as well as ICU mortality, Glasgow Coma Scale (GCS) score, Acute Physiology and Chronic Health Evaluation (APACHE II), and Injury Severity Scores (ISS), were recorded. In addition to head injuries, associated injuries to the chest, abdomen, pelvis, spine, and extremities were also recorded. The Guilan University of Medical Sciences Ethics Committee approved the study protocol.

Data analysis plan

Statistical analysis was performed using SPSS, version 16. Data were reported as the mean ± SD. Assuming the violation of parametric assumptions, interval data were analyzed using the two-tailed Student's t test and categorical variables were compared using the χ^2 test. There is ample evidence indicating that the power of the t test is comparable to that of the Mann–Whitney U test when the assumption of homogeneity of variance is violated, i.e., the t test and F test are barely affected by non-normality of the sample distribution [26]. Subsequently, using variables that were significantly associated with ICU mortality at the bivariate level of analysis, we performed hierarchical forward stepwise selection with switching to identify the best independent predictors for ICU mortality. Statistical significance was defined as $p < 0.05$ for all comparisons.

Results

Two hundred twenty-eight trauma patients were admitted to the ICU during the one-year study period. Of the 115 patients enrolled in the study, 63 (28 %) were identified as obese (mean BMI = 34.5 ± 6.7 kg/m^2) and 52 (72 %) were identified as non-obese (mean BMI = 21.8 ± 5.3 kg/m^2) (Table 1). Despite no significant difference in age, gender, ISS, and admission GCS score between the two groups, obese patients had significantly higher ICU mortality than non-obese patients ($p = 0.02$). In addition, we found no significant difference between the obese and non-obese patients in the different ISS groups: ISS < 15 (28 vs. 18 %, $p = 0.21$), ISS 16–25 (32 vs. 33 %, $p = 0.91$), ISS > 25 (40 vs. 49 %, $p = 0.33$). However, there was a trend toward higher ICU mortality in obese patients with ISS > 25 compared to non-obese patients with the same ISS.

Obesity and ventilation use, ICU, and hospital length of stay

The number of patients who required mechanical ventilation was statistically higher in the obese group compared to the non-obese group (62 vs. 43 %), ($p = 0.04$). Obese patients required more days of mechanical ventilation compared to non-obese patients ($p < 0.001$). Also, longer ILOS (21 vs. 18.4 days) ($p = < 0.001$) and HLOS (30 vs. 24.4 days), ($p = < 0.001$) were observed in obese patients compared to non-obese patients (Table 1). To further evaluate the effect of obesity on ICU mortality, regression analysis was done using APACHE II and BMI, age, and GCS score as predictors (Table 2). Subsequently, age (OR = 1.04; CI = 0.98–1.09), BMI (OR = 2.4; CI = 1.2–9.6), and GCS score (OR = 2.3; CI = 1.6–4.3) were found to be independent predictors of patient mortality (Table 2).

Table 1 Characteristics of obese and non-obese patients in the study

Variables	Obese ($n = 63$)	Non-obese ($n = 52$)	p value
Age (years)	48 ± 23	46 ± 18	0.61
Male gender (%)	74	66	0.35
BMI (mean ± SD)[a]	34.5 ± 6.7	21.8 ± 1.8	<0.001
ISS[b]	23.7 ± 4.33	23.2 ± 5.75	0.59
ISS ≤ 15 (%)	28	18	0.21
ISS 16–25 (%)	32	33	0.91
ISS > 25 (%)	40	49	0.33
GCS score (mean ± SD)[c]	8 ± 4	9 ± 5	0.24
ICU mortality (number)	39	19	0.02
ILOS (days)[d]	21 ± 3.2	18.4 ± 4.5	<0.001
HLOS (days)[e]	30 ± 3.8	24.4 ± 4.6	<0.001
Requiring mechanical ventilation (%)	62	43	0.04
VD[f]	7.2 ± 4.6	3.2 ± 1.8	<0.001

$p > 0.05$ was considered to signify nonsignificance

[a] Body mass index

[b] Injury Severity Score

[c] Glasgow Coma Scale

[d] ICU length of stay

[e] Hospital length of stay

[f] Ventilator days

Table 2 Independent predictors of ICU mortality

Variables	OR (95 % CI)	p value
APACHE II score	5.8 (1.1–19.4)	0.07
Age	1.04 (0.98–1.09)	0.04
BMI	2.4 (1.2–9.6)	0.02
GCS score	2.3 (1.6–4.3)	0.03

Differences were defined as being significant if $p < 0.05$

Discussion

This article investigates the impact of obesity on treatment outcomes of patients with TBI. Results indicate that obese patients had higher ICU mortality compared to non-obese patients, despite similarities in age, sex, GCS score and ISS. BMI > 30 was an independent predictor for a patient's ICU mortality, and there was a trend toward higher mortality in obese patients with ISS > 25. The effect of obesity on mortality has been examined in post-traumatic patients in several studies employing somewhat different methodologies, which yielded different results [10, 11]. One earlier study reported that severely overweight blunt trauma patients had a 42.1 % higher mortality rate than their average or overweight counterparts [27]. In a prospective study, BMI > 27 was an independent predictor of increased severity of illness, and was associated with higher standardized mortality rates (SMR) [15]. In another prospective study, authors reported that obese patients were 7.1 times more likely to have a higher risk of mortality [8]. However, findings from 2,108 critically injured trauma patients (one of the largest studies to date) reveal that morbid obesity (BMI ≥ 40) increased morbidity, ILOS, and HLOS, but had no demonstrated effect on mortality [12].

Our findings also suggest an association between obesity with ILOC and HLOS. Obese patients in our sample had stayed in the ICU nearly 4 days longer, and had slightly over 6 days longer hospital lengths of stay, compared to the non-obese patients. This is consistent with other empirical evidence linking obesity to poor prognoses in obese trauma patients, mainly due to complications [11, 16, 28]. It has also been suggested that a rise in blood pressure [13, 29], increased numbers of respiratory complications [23, 27], multiple organ failure [9], infectious morbidity, and wound dehiscence [10] are among the BMI-related complications affecting treatment outcomes in obese trauma patients.

Obese patients in our study were also much more likely to receive mechanical ventilation. In addition, the duration of mechanical ventilation in obese patients was longer than in non-obese patients ($p = 0.04$). It is reported that, compared to individuals who weigh less, patients who weigh more than 114 kg need two to four times the mechanical work required to passively ventilate [30]. In sedated, morbidly obese patients, lung and chest disorders, as well as reduced lung volume, result in obstruction during mechanical ventilation [31]. In addition, obese patients are more likely to have difficult tracheal intubation and frequent post-extubation for management of mechanical ventilation [32], chronic obstructive pulmonary disease (COPD) [12], heart failure [4], sleep apnea, hypoventilation, and reduced respiratory function and well-being [14, 33–35]. These findings suggest the need for further cost analysis studies to help identify and allocate resources in managing this patient population [22].

Our results also indicate that an increase in age and low GCS score (8 ± 4) were independently associated with increased ICU mortality, consistent with previous findings [25, 36, 37]. Sifri et al. [28] reported that old age, rather than obesity, was a crucial risk factor for mortality in obese ICU-admitted TBI patients. In another study, unfavorable outcomes operationalized as mortality were more frequent in TBI patients 50 years of age and older who were admitted to three neuro-ICUs. The authors recommend considering age a possible risk factor for mortality in TBI patients, as this can improve clinician decisions when triaging those in need of ICU care [38].

Traumatic brain injury (TBI) patients are clinically evaluated by applying the GCS (a neurological scale) to determine their stage of mental functioning and consciousness [37, 39–41]. The GCS is also used to predict

mortality in TBI patients. In a study of elderly patients admitted to the ICU, low GCS score was identified as an independent predictor for short-term and long-term mortality [36]. Some investigators argue that the GCS profile is a more reliable tool for determining a prognosis than the total GCS score [42]. This warrants further research to compare the predictive power of the total GCS score versus separate component scores in treatment outcomes of obese versus non-obese TBI-ICU patients.

Some limitations should be considered when interpreting the findings of this study. We were unable to determine the impact of different levels of obesity on mortality. It is reported that the association between BMI and mortality varies among groups with different BMI levels, suggesting higher odds of hospital death in patients with the lowest BMI as well as in those with the highest (>35) [7, 18, 43]. Because of our relatively small sample of underweight patients, we were not able to test for the impact of this factor on mortality in this study. Moreover, we were not able to account for the role of confounding variables such as pre-existing conditions, co-morbidities [3], and individual differences in ICU practices [15] on mortality outcomes, as these data were not collected. Considering that morbidly obese patients are at higher risk for developing complications [4, 12], their impact on mortality outcome should be tested in future prospective studies.

Our findings are also limited in regards to testing the association between types of injury and mortality. As suggested by Evans et al. [7], obese patients sustain different types of injuries compared to non-obese patients, which may lead to different treatment outcomes. In our study, the primary injury for the majority of patients was brain injury, and the number of patients with other types of injuries was negligible, limiting our ability to test the association between types of injury and mortality outcome. We, however, found no association between ISS and mortality.

Despite these limitations, our findings add to the limited body of knowledge on obesity as an independent risk factor for morbidity in ICU-TBI obese patients. Our results also add to the existing literature that express the need for evidence-based protocols that will ensure best practices in managing ICU-TBI obese patients.

Conclusion

Obese patients with TBI in our study had higher ICU mortality than non-obese patients. Our findings suggest that closer attention is warranted when treating obese patients in the ICU. They also point to the need for further prospective studies, using larger samples. These should test the association between multiple types of data, including patient-centered data, pre-hospital admission data, and ICU admission and management data, in order to logically delineate the impact of obesity on mortality in this patient population.

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Conflict of interest The authors have no conflict of interest to report.

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