Obesity Is an Independent Risk Factor of Mortality in Severely Injured Blunt Trauma Patients

Angela L. Neville, MD; Carlos V. R. Brown, MD; Janie Weng, BS; Demetrios Demetriades, MD, PhD; George C. Velmahos, MD, PhD

Hypothesis: Obesity is associated with increased morbidity and mortality in critically injured blunt trauma patients.

Design: Case-control study of all critically injured blunt trauma patients between January 2002 and December 2002.

Setting: Academic level I trauma center at a county referral hospital.

Patients: Two hundred forty-two consecutive patients admitted to the intensive care unit following blunt trauma. Patients were divided into 2 groups by body mass index. The obese group was defined as having a body mass index of 30 kg/m² or higher, and the nonobese group was defined as having a body mass index lower than 30 kg/m².

Main Outcome Measures: Univariate and multivariate analyses were performed to identify risk factors for mortality. Complications and length of stay were also evaluated.

Results: Of the 242 patients, 63 (26%) were obese, and 179 (74%) were nonobese. The obese and nonobese groups were similar with regard to age (mean ± SD, 49 ± 18 years vs 45 ± 22 years), male sex (63% vs 72%), Glasgow Coma Scale score (mean ± SD, 11 ± 5 vs 11 ± 5), and injury severity score (mean ± SD, 21 ± 13 vs 20 ± 14). The obese group had a higher body mass index (mean ± SD, 35 ± 7 vs 24 ± 3; P < .001). Mechanisms of injury and injury patterns were similar between groups. The obese group had a higher incidence of multiple organ failure (13% vs 3%; P = .02) and mortality (32% vs 16%; P = .008). Obesity was an independent predictor of mortality with an adjusted odds ratio of 5.7 (95% confidence interval, 1.9-19.6; P = .003).

Conclusions: Critically injured obese trauma patients have similar demographics and injury patterns as nonobese patients. Obesity is an independent predictor of mortality following severe blunt trauma.

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U NINTENTIONAL INJURY REMAINS the fifth leading cause of death in the United States. Meanwhile, the number of overweight individuals climbs at an alarming rate. Recent estimates from an epidemiological review found 18.9% of the US population to be obese, defined by a body mass index (BMI) of 30 or higher. (BMI is the weight in kilograms divided by the height in meters squared.) An understanding of the interplay between these 2 health care epidemics is paramount.

Obesity imparts anatomical and physiological changes that may interfere with the body's response to injury. Obese patients have a compromised pulmonary status characterized by reduced lung volumes and compliance, as well as increased ventilation/perfusion mismatching. Obesity is an independent risk factor for cardiovascular disease, which can complicate any hospitalization. Higher incidences of deep venous thrombosis, gastroesophageal reflux, and insulin resistance also afflict obese patients.

The obese habitus additionally affects our ability to care for such patients. Obesity makes airway management more challenging, surgical exposures more difficult, and radiographic imaging less reliable. For these reasons, we hypothesized that obesity would be associated with increased morbidity and mortality in critically injured trauma patients. The objective of this study was to characterize the relationship between obesity and blunt trauma outcomes.

METHODS

We evaluated all blunt trauma admissions to the surgical intensive care unit (SICU) at our academic level I trauma center from January 2002 to December 2002. Data on each patient was extracted from both a trauma registry and...
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Table 1. Admission Characteristics*

<table>
<thead>
<tr>
<th></th>
<th>Obese Group (n = 63)</th>
<th>Nonobese Group (n = 179)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>age, y</td>
<td>49 ± 18</td>
<td>45 ± 22</td>
<td>.08</td>
</tr>
<tr>
<td>men, %</td>
<td>63</td>
<td>72</td>
<td>.23</td>
</tr>
<tr>
<td>heart rate, beats/min</td>
<td>98 ± 35</td>
<td>99 ± 27</td>
<td>.99</td>
</tr>
<tr>
<td>systolic blood pressure, mm Hg</td>
<td>123 ± 36</td>
<td>130 ± 28</td>
<td>.24</td>
</tr>
<tr>
<td>Glasgow Coma Scale score</td>
<td>11 ± 5</td>
<td>11 ± 5</td>
<td>.34</td>
</tr>
<tr>
<td>body mass index, kg/m²</td>
<td>35 ± 7</td>
<td>24 ± 3</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

*Data are presented as mean ± SD unless otherwise indicated.

Figure 1. Types of complications encountered in obese and nonobese patients and their relative frequencies.

Table 2. Types of complications and their relative frequencies are depicted in Figure 1. There were no statistically significant differences in the frequency of complications between the groups with one exception. The obese group had a higher rate of MOF than the nonobese group (13% vs 3%; P = .02). Obese and nonobese survivors had the same SICU length of stay (mean ± SD, 10 ± 9 days vs 11 ± 10 days; P = .65) and overall length of stay (mean ± SD, 24 ± 23 days vs 21 ± 17 days; P = .47).

The mortality rate for the entire population was 20% (n = 49), but obese patients had a 2-fold higher mortality rate (32% [n = 20] vs 16% [n = 29]; P = .008). The causes of mortality and the average time to mortality are reported in Table 2. The most common causes of death in both groups were brain injury (67%) and MOF (24%). There was no statistical difference overall in the cause of death between groups (Figure 2). However, MOF as the cause of death was twice as frequent in obese patients (7 of 20 or 35%) than in nonobese patients (3 of 29 or 17%; P = .16). The following were identified as independent risk factors for mortality: obesity, head injury, pulmonary contusion, ISS, and age, as shown in Table 3.

Figure 2. Types of complications encountered in obese and nonobese patients and their relative frequencies.

After the 1-year study period, 242 blunt trauma patients were admitted to the SICU. The population had a mean ± SD age of 45 ± 21 years, was 69% male, and had a mean ± SD ISS of 20 ± 17. Of these patients, 63 (26%) were obese (mean ± SD BMI, 35 ± 7), and 179 (74%) were nonobese (mean ± SD BMI, 24 ± 3). Admission characteristics of the 2 groups are shown in Table 1. Mechanism of injury did not differ between the 2 groups (P = .15). The most frequent mechanisms of injury were motor vehicle accident (37%), pedestrian struck by auto (33%), fall (14%), motorcycle accident (7%), assault (4%), and other (5%). Injury patterns were similar for obese and nonobese patients, with the exception that obese patients had fewer basilar skull fractures (2% vs 13%; P = .01) and more femur fractures (22% vs 10%; P = .01). Mean ± SD ISS were 21 ± 13 for the obese group and 20 ± 14 for the nonobese group (P = .31).

Complications occurred with equal frequency in both the obese and the nonobese groups (35% vs 36%; P = .91). Types of complications and their relative frequencies are depicted in Figure 1. There were no statistically significant differences in the frequency of complications between the groups with one exception. The obese group had a higher rate of MOF than the nonobese group (13% vs 3%; P = .02). Obese and nonobese survivors had the same SICU length of stay (mean ± SD, 10 ± 9 days vs 11 ± 10 days; P = .65) and overall length of stay (mean ± SD, 24 ± 23 days vs 21 ± 17 days; P = .47).

The mortality rate for the entire population was 20% (n = 49), but obese patients had a 2-fold higher mortality rate (32% [n = 20] vs 16% [n = 29]; P = .008). The causes of mortality and the average time to mortality are reported in Table 2. The most common causes of death in both groups were brain injury (67%) and MOF (24%). There was no statistical difference overall in the cause of death between groups (Figure 2). However, MOF as the cause of death was twice as frequent in obese patients (7 of 20 or 35%) than in nonobese patients (3 of 29 or 17%; P = .16). The following were identified as independent risk factors for mortality: obesity, head injury, pulmonary contusion, ISS, and age, as shown in Table 3.

Table 3. Comment

Obesity imparts a number of anatomical and physiological changes that may impact the body’s response to injury. Our study finds that although obese and nonobese severe blunt trauma patients have similar demograph-
ics, injury patterns, and complication rates, obese patients are more than 5 times more likely to die from their injury than their nonobese counterparts.

Our study adds to a somewhat controversial body of literature that has failed to find a clear association between obesity and trauma outcomes. In the early 1990s, 3 retrospective studies, using 3 different definitions of obesity, looked at the effects of obesity on trauma mortality.\(^5,6,10\) Using a statewide discharge database from California, Morris et al\(^8\) evaluated the effect of preexisting medical conditions on trauma deaths. Secondary diagnoses that were ICD-9 coded on the discharge record made up the preexisting medical conditions. Obesity was one such diagnosis and was not associated with an increased mortality. Limitations of this study include the significant potential for underreporting secondary diagnoses (like obesity) and the probability that there was no uniform definition of obesity among the different hospitals coding the discharge records.

Milzman et al\(^9\) looked at prospectively collected trauma registry data to determine the impact of 9 preexisting illnesses on trauma outcomes. Obesity, defined as female body weight of more than 200 pounds or male body weight of more than 250 pounds, was the only disease that was not independently associated with an increased mortality. Their use of an unconventional definition of obesity and the fact that only 2.1% of their population was obese make it difficult to draw conclusions from this study about the effect of obesity on trauma mortality.

Our study's overall mortality rate of 20% is in excess of the approximately 10% predicted mortality rate of blunt injured patients with an age of less than 55 years and an ISS in the range of 16 to 24.\(^11\) It also exceeds the average mortality rate of 9% found in the Smith-Choban study; their mean ISS was 22.\(^10\) This difference between mortality rates may be because our population was slightly older than the Smith-Choban population (mean age, 45 vs 34 years) and more obese (26% with BMI>30 vs 10% with BMI>31), or it may reflect the limitations of the ISS.

We and Smith-Choban and colleagues find increased BMI to be an independent predictor of mortality. The strength of our study lies in the fact that we have a relatively large obese population (n=63) and that no patients were excluded. Each consecutive admission to our SICU had height and weight measurements taken; thus, BMI was reliably calculated. The Smith-Choban study excluded 177 patients on the basis of incomplete height and weight records; furthermore, they had a relatively small group of patients with a BMI of higher than 31 (n=19).\(^10\) Our study also uses the now widely accepted definition of obesity (BMI≥30), and thus our con-

### Table 2. Causes of Mortality and Length of Time to Death

<table>
<thead>
<tr>
<th>Cause of Mortality</th>
<th>Obese Group, No.</th>
<th>Nonobese Group, No.</th>
<th>Mean ± SD Time to Mortality (Obese vs Nonobese), d</th>
<th>P Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closed head injury</td>
<td>12</td>
<td>21</td>
<td>8 ± 18 vs 6 ± 7</td>
<td>.7</td>
</tr>
<tr>
<td>Multiple organ failure</td>
<td>7</td>
<td>5</td>
<td>27 ± 32 vs 8 ± 5</td>
<td>.2</td>
</tr>
<tr>
<td>Respiratory failure</td>
<td>1</td>
<td>0</td>
<td>5†</td>
<td>NA</td>
</tr>
<tr>
<td>Exsanguination</td>
<td>0</td>
<td>3</td>
<td>2 ± 1‡</td>
<td>NA</td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
<td>29</td>
<td>15 ± 25 vs 6 ± 7</td>
<td>.1</td>
</tr>
</tbody>
</table>

Abbreviation: NA, not available.

*P value reflects comparison between the mean times to mortality in obese and nonobese groups.
†Obese group only.
‡Nonobese group only.

### Table 3. Independent Risk Factors of Mortality

<table>
<thead>
<tr>
<th>Cause of Mortality</th>
<th>Adjusted Odds Ratio (95% Confidence Interval)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe head injury</td>
<td>34.8 (8.9-165.9)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Pulmonary contusion</td>
<td>10.4 (2.9-41.8)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Body mass index ≥30</td>
<td>5.7 (1.9-19.6)</td>
<td>.003</td>
</tr>
<tr>
<td>Injury Severity Score ≥20</td>
<td>4.6 (1.4-17.5)</td>
<td>.01</td>
</tr>
<tr>
<td>Age &gt;55 y</td>
<td>1.6 (1.3-2.2)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Figure 2. Causes of mortality and their relative percentages in obese and nonobese subgroups.
clusions are easily interpretable within the context of the current literature.

Although our study helps to establish a link between obesity and trauma mortality, it falls short in explaining this relationship. We are still hampered by an incomplete understanding of the pathophysiology of obesity and its effects on trauma outcome. Could it be that obese patients are subject to a different injury pattern than their nonobese counterparts? Our study found that obese patients had similar mechanisms of injury and relatively similar injury patterns as nonobese patients. Obese patients had fewer basilar skull fractures, yet blunt head injury remained the most common cause of mortality in this population. In a prospective review of injury patterns in 743 obese blunt trauma patients, Boulanger et al.12 found that obese patients were more likely to have rib fractures, pulmonary contusions, pelvic fractures, and extremity fractures and less likely to have head trauma or liver injury; this study, however, did not look at outcomes. While head injury remains the most common cause of mortality in obese blunt trauma patients, Boulanger and colleagues' study and our study suggest that obese patients tend to have less head trauma. It thus seems unlikely that injury pattern is a major contributor to their worse outcome. Nevertheless, a better correlation between injury patterns and outcomes in this population would be useful.

Could it be that comorbid conditions associated with obesity lead to its apparent increased mortality and that we are missing confounding factors? It is well established that obesity predisposes patients to multiple medical conditions. Obesity is independently associated with coronary artery disease, systemic hypertension, and heart failure.13 A patient's BMI is one of the strongest predictors of diabetes.14 Hypercholesterolemia and chronic hypoxia and hypercapnia are also associated with obesity.15 The results of Morris et al.4 and Milzman et al.,5 who both found that preexisting medical conditions, but not obesity, increased trauma mortality, support this theory. Both studies found cardiac disease, and Morris' study found diabetes, to be associated with increased mortality. Prospective studies identifying comorbid conditions at the time of admission, evaluating objective parameters such as admission blood glucose and creatinine levels, and comparing outcomes in obese vs nonobese patients may help answer this important question.

Finally, is it possible that the inflammatory response triggered in severe trauma could have an altered, more fatal manifestation in the obese patient? Our study found an increased incidence of MOF in the obese group of patients. Furthermore, there was a trend toward obese patients dying from MOF compared with their nonobese counterparts. In the study by Smith-Choban et al.10 7 of the 8 severely overweight trauma patients died from acute respiratory distress syndrome, an inflammatory-mediated event. Finally, an investigation of morbidly obese patients in a medical intensive care unit found the presence of MOF to be the strongest independent predictor of mortality in these patients.16 One is forced to consider the impact of obesity on the inflammatory response.

There is increasing evidence that leptin, the adipocyte-secreted hormone that helps regulate adiposity, has immunomodulatory actions.17 Leptin is structurally similar to the interleukin-6 cytokines and has been shown to be important in immunocompetency.18 In vitro models show that leptin may have a role in increasing phagocytic activity in macrophages, and animal studies reveal that leptin-deficient mice are more prone to lipopolysaccharide-induced lethality.17 Human studies find survivors of severe sepsis and septic shock to have higher plasma levels of leptin than nonsurvivors.19 No studies have looked at leptin levels in trauma patients. Interestingly, obese persons have high baseline plasma leptin concentrations. The fact that their high leptin levels do not correlate with the expected feedback responses (to decrease food intake and increase energy expenditure) suggests that obese persons may be resistant to leptin.20 Could it be possible that leptin resistance in the obese population makes them more prone to inflammatory complications? The role of leptin in the inflammatory cascade is still being evaluated and will need to be studied in the context of obesity. The role of leptin in trauma, a significant but clearly different mediator of the inflammatory response, remains to be seen.

Our study has several limitations. Although we have found an association between obesity and trauma mortality, we can only hypothesize about the reason(s) for this association. Because of the retrospective nature of the study, we were not able to account for other medical conditions that may have confounded our results and led to an increased mortality in this group. Similarly, although we found a trend toward death from MOF in obese patients, we were unable to identify precipitating factors of MOF (such as types of infection or transfusion requirements). Having such information might have helped elucidate the underlying causes of increased death in the obese population. Our study is also limited by the size of the patient population. A larger patient population would have allowed us to stratify levels of BMI to determine any correlation with injury outcome. A larger population also might have identified statistically significant differences in causes of mortality that showed clinically important trends. A study that intends to address these limitations is currently being designed at our institution.

In this retrospective analysis of 242 severely injured blunt trauma patients, we found that obese patients have similar demographics, mechanisms of injury, and injury patterns but higher mortality than their nonobese counterparts. Multiple organ failure occurs more often as a complication in obese patients and is twice as often the cause of death in this population. Obesity, as an independent risk factor, carries a nearly 6-fold increase in mortality rate. This study has important prognostic implications for obese patients, suggesting they be considered a high-risk group for mortality after sustaining severe blunt trauma. Further study to better delineate the relationship between obesity and trauma is warranted.

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The Incidence of Recurrent Venous Thromboembolism After Treatment With Vitamin K Antagonists in Relation to Time Since First Event: A Meta-analysis

Carlo J. J. van Dongen, MSc; Roel Vink, MD; Barbara A. Hutten, PhD; Harry R. Büllner, MD, PhD; Martin H. Prins, MD, PhD

Background: After a first episode of venous thromboembolism, patients are treated with vitamin K (phytonadione) antagonists. There are indications that the risk of recurrence after treatment with vitamin K antagonists decreases relative to the time since the first event. The aim of the present meta-analysis is to describe the risk of recurrent venous thromboembolism after treatment with vitamin K antagonist in relation to the time since the index event.

Methods: Computerized searches in MEDLINE and EMBASE databases; reference checks of pertinent articles; personal communication with colleagues to find randomized clinical trials and cohort studies in which patients with venous thromboembolism were treated with vitamin K antagonists. Per treatment arm, 2 reviewers independently extracted data on the number of recurrent events and the duration of follow-up per time period of 3 months.

Results: A total of 135 potentially eligible studies were identified. Of these, 18 studies could be included, comprising 25 treatment arms that could be analyzed. Treatment arms were divided into 3 groups based on treatment duration (short, medium, and long). For all 3 groups, the monthly incidence immediately after discontinuation of treatment was high and declined rapidly thereafter. The monthly incidence after 9 months seemed independent of the treatment duration.

Conclusions: There is a diminishing risk of recurrent venous thromboembolism over time and a stabilization after 9 months independent of the duration of the initial treatment with vitamin K antagonists. These findings have important implications for decision making about the optimal duration of treatment with vitamin K antagonists.

 Correspondence: Carlo J. J. van Dongen, MSc, Department of Clinical Epidemiology and Biostatistics, Room J2-204, Academic Medical Center, University of Amsterdam, PO Box 22700, 1100 DE Amsterdam, the Netherlands (c.j.vandongen@amc.uva.nl).