The Effect of Body Mass Index on Posttraumatic Transfusion after Pelvic Trauma

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The impact of body mass index (BMI) on posttraumatic blood transfusion after pelvic trauma is not well known. We conducted a retrospective review of trauma registry data over a 5-year period. Patients were stratified by BMI as normal: less than 25 kg/m^2, overweight: 25 to 29.9 kg/m^2, obese: 30 to 39.9 kg/m^2, and morbidly obese: 40 kg/m^2 or greater. Fractures were identified as "likely to receive transfusion" based on literature. Multivariable logistic regression modeling evaluated the relationship between BMI and initial posttraumatic transfusion. A second regression model was created to test the effect of BMI after adjusting for fractures "less likely to receive transfusion." Sixty-six of 244 patients (27.3%) received transfusion (mean: 1.1 ± 2.3 units). Morbid obesity was associated with transfusion (less than 55.6 *vs* 24.8%; $P < 0.05$) and units of total blood transfused (2.2 ± 2.9 *vs* 1.0 ± 2.2 mL; $P < 0.05$). The average age of patients who received a blood transfusion was significantly older compared with patients who did not receive a transfusion (45.4 ± 18.8 *vs* 36.1 ± 16.1 years; $P < 0.05$). After adjusting for potential confounders, morbid obesity was a significant risk factor for transfusion (odds ratio [OR], 4.1; 95% confidence interval [CI], 1.4 to 12.0). Adjusting by age and fracture patterns "less likely to receive transfusion," morbid obesity remained a risk factor for transfusion (OR, 4.5; 95% CI, 1.5 to 12.9). Morbid obesity represented a significant risk factor for posttraumatic transfusion in isolated pelvic trauma, even for fracture patterns "less likely to receive transfusion."

THE WORSENING OBESITY epidemic in the United States as well as other industrialized nations is well documented.[1–3] Obesity is quantified by body mass index (BMI), defined as weight (kg) divided by the square of height (m^2). Ideal BMI is often referenced as 18.5 to 24.9 m/kg^2 with values greater than 30 kg/m^2 considered obese.[3] The relevance in trauma surgery is significant because current literature has identified differences between obese and nonobese patients with regard to blunt traumatic injuries.[4–9] Porter et al.[10, 11] described separately the rates of complications after pelvic fracture and acetabular fracture surgery in patients with an elevated BMI, highlighting increased postoperative complications, operative time, intraoperative blood loss, and need for subsequent surgery.

Although it is commonly accepted that obesity represents a risk for complications after traumatic injuries,[6, 10–12] a "cushion effect" has been described in which increased BMI is associated with less severe abdominal Abbreviated Injury Scale scores.[9] This raises the question of whether obesity confers a relative advantage by "cushioning" the abdominal and pelvic contents from blunt injury and subsequent bleeding. There are presently few studies in the literature evaluating the relationship of BMI to posttraumatic transfusion after high-energy pelvic injuries. The purpose of this investigation is to evaluate the effect of morbid obesity on posttraumatic transfusion after isolated pelvic and/or acetabular injuries. Based on the theory of the "cushion effect," we hypothesize that morbid obesity is associated with decreased risk for posttraumatic and presurgical transfusion after pelvic trauma.

Methods

Institutional Review Board approval was obtained before study initiation. Patients with pelvic and/or acetabulum fractures who presented to an academic Level I trauma center during a 5-year period were retrospectively identified from the institution's Trauma Registry of the American College of Surgeons database.

Presented as a podium presentation at the American Academy of Orthopaedic Surgeons, February 2011, San Diego, California.

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Demographic data, Injury Severity Score (ISS),[13] admission hematocrit (%), emergency department (ED) pulse (beats per minute), ED systolic blood pressure (mmHg), and units of blood transfusion in the first 24 hours after admission to the trauma center, or until the time of operative intervention if within 24 hours were recorded. Early operative fixation was documented within 24 hours of hospital admission. Considering the primary objective of the study, intraoperative and postoperative transfusion were not included as part of the analysis so as not to confound the evaluation of potential blood loss and transfusion requirements in the initial trauma resuscitation period. Complete inclusion and exclusion criteria are outlined in Table 1. Three hundred eighty-two patients with pelvic and/or acetabular fractures were identified for potential study inclusion. BMI was calculated for each patient based on height and weight data obtained from the initial trauma admission history and physical examination. As a result of the retrospective nature of the study, we were unable to determine if height and weight data were self-reported. Patients were stratified into four BMI classes: normal (less than 25 kg/m^2), overweight (25 to 29.9 kg/m^2), obese (30 to 39.9 kg/m^2), and morbidly obese (40 kg/m^2 or greater), as defined by the National Heart, Lung, and Blood Institute[14] and the World Health Organization.[15] Breakdown of the study population by BMI is described in Table 2.

Radiographic Fracture Classification

A fellowship-trained orthopaedic trauma surgeon with greater than 15 years experience and who served as the institution's primary pelvic and acetabular surgeon supervised fracture classification by radiographic data. Complete diagnostic imaging studies were reviewed and included admission anteroposterior (AP), inlet, and outlet views for patients with pelvic ring injuries and AP, iliac oblique, and obturator oblique images for patients with fractures of the acetabulum. Computed tomography (CT) scans were crossreferenced when the fracture patterns were not clearly delineated on radiographs. Pelvic fractures were described by the Young and Burgess classification system,[16] and acetabular fractures were classified by the Letournel System.[17]

Fractures were considered "likely to receive transfusion" or "less likely to receive transfusion" according to literature by Magnussen and colleagues[18] describing the association of blood transfusion and pelvic and acetabular fracture characteristics. Pelvic fractures considered "likely to receive transfusion" were characterized by major ligament disruption and included anteroposterior compression Types II and III, lateral compression Type III, vertical shear, and combined mechanism.[19–21] Acetabulum fractures involving the anterior column (anterior column [AC], AC posterior hemitransverse, and both column), and T-type fractures were also considered "likely to receive transfusion."[22–24] All other pelvic and acetabulum fractures were classified as "less likely to receive transfusion." Patients who sustained combined pelvic and acetabulum fractures were also identified as a potential confounding variable. Such injuries have been shown to receive more frequent transfusion and significantly greater amounts of transfused blood product than either pelvic or acetabular injuries alone.[25, 26]

TABLE 1. *Inclusion and Exclusion Criteria*

Inclusion Criteria	Exclusion Criteria
Fracture of the bony pelvis or acetabulum	Abbreviated Injury Scale score >2 in any body region other than that involving the pelvis
Skeletally mature	Long-bone fracture*
Complete BMI data	Ballistic injuries
	Pediatric fractures
	Avulsion injuries

* Defined as fracture of the humerus, radius and ulna, femur, or tibia.
BMI, body mass index.

Statistical Methods

Descriptive statistics were used to summarize all study variables (means, standard deviations, and frequency) and to determine the distribution of patients requiring blood transfusion and the total amount of red blood cell (RBC) units transfused. Dichotomous and categorical variables were evaluated with χ^2 testing to determine the relationship to the frequency of blood transfusion. Student's t test and the Mann-Whitney U test were used when considering parametric and nonparametric dichotomous variables, respectively, for comparison to a continuous outcome of total RBC units transfused. Multiple variable groups (more than two groups) were compared with a one-way analysis of variance or Kruskal-Wallis test when considering a continuous outcome. A multivariable logistic regression analysis was conducted testing the effect of BMI classification on the rate of blood transfusion after adjusting for potential confounding variables age, fracture patterns "likely to receive transfusion," and combined pelvic/acetabulum fractures. Similarly, the effect of BMI classification on the rate of transfusion was evaluated after adjusting for fractures "less likely to receive transfusion" and age. Results are reported as an odds ratio (OR) with 95 per cent confidence interval (CI). Statistical significance was considered for P value < 0.05.

TABLE 2. *Study Population by Body Mass Index*

	<25 kg/m^2	25–29.9 kg/m^2	30–39.9 kg/m^2	≥40 kg/m^2
Number of patients	104	72	50	18
Pelvic fracture, no. (%)	47 (45.2)	29 (40.3)	16 (32.0)	3 (16.7)
Acetabulum fracture, no. (%)	46 (44.2)	32 (44.4)	29 (58.0)	11 (61.1)
Combined pelvic/acetabulum, no. (%)	11 (10.9)	11 (15.3)	5 (10.0)	4 (22.2)
ISS (SD)	12.7 (4.3)	13.3 (4.8)	12.6 (4.1)	12.3 (3.0)
Mean transfusion* (SD)	0.82 (1.94)	1.18 (2.13)	1.22 (1.22)	2.17 (2.92)

* $P < 0.05$.
ISS, Injury Severity Score; SD, standard deviation.

Results

Complete radiographic, transfusion, and BMI data were available for 244 of 382 (63.9%) patients. Mean age for the study population was 38.6 ± 17.3 years (range, 18 to 90.7 years), and 170 of 244 (69.7%) patients were male. Mean ISS was 12.8 ± 4.4. Pelvic fractures were identified in 95 of 244 (38.9%) patients, and acetabular fractures were classified in 118 of 244 (48.4%) patients. Of the entire study population, combined pelvic/acetabular fractures were documented in 31 of 244 (12.7%) patients. Mean ISS was similar when compared by pelvic (13.0 ± 3.5) and acetabulum fractures (12.7 ± 4.1; $P = 0.5$). Injury severity in combined pelvic/acetabulum injuries was not different when compared with the rest of the population (12.2 ± 3.5 *vs* 13.0 ± 4.5, $P = 0.4$). Fifty-three (21.7%) patients underwent fracture fixation within 24 hours; there was no difference in ISS in patients who underwent early operative intervention (12.4 ± 4.2 *vs* 12.9 ± 4.4, $P = 0.46$).

Sixty-six (27.0%) patients received a blood transfusion and the average amount of RBCs transfused were 1.1 ± 2.3 units (range, 1 to 12 units). Patients who received blood had a significantly lower admission hematocrit (35.6 ± 5.2 *vs* 39.3 ± 4.8, $P < 0.001$) and elevated ED pulse (96.8 ± 16.3 *vs* 90.1 ± 16.7 beats/min, $P = 0.003$). There was no difference in ED systolic blood pressure (128.7 ± 21.3 *vs* 131.7 ± 21.8 mmHg, $P = 0.26$). The average age of patients who received a blood transfusion was significantly older compared with patients who did not receive a transfusion (45.4 ± 18.7 *vs* 36.1 ± 16.1 years, $P = 0.0002$). There were no significant differences in the incidence of transfusion in fractures that underwent early operative intervention compared with fractures that underwent fixation greater than 24 hours (17.0 *vs* 29.8%, $P = 0.06$) or the amount of blood transfused before operative intervention (0.51 ± 5.11 *vs* 1.3 ± 2.4, $P = 0.11$).

Of the entire study population, fractures considered "likely to receive transfusion" received blood more frequently (60.6 *vs* 39.4%, $P < 0.001$) and in significantly greater amounts (2.1 ± 3.1 mL; range, 0 to 12 mL *vs* 0.5 ± 1.3 mL; range, 0 to 7 mL; $P < 0.0001$) than fractures considered "less likely to receive transfusion." The difference in transfusion frequency (25.8 *vs* 7.3%, $P < 0.001$) and total amount of RBCs transfused (2.6 ± 3.1; range, 0 to 10 *vs* 0.9 ± 2.1; range, 0 to 12; $P < 0.0001$) in combined pelvic and acetabulum injuries was significantly different when compared with patients with only a pelvic or acetabulum fracture. ISS was not associated with a greater incidence of transfusion (12.8 ± 3.9 *vs* 12.8 ± 4.6; $P = 0.92$) among combined fractures.

Mean BMI was 27.4 ± 6.8 kg/m^2 and distribution by BMI class consisted of less than 25 kg/m^2: 104 (42.6%); 25 to 29 kg/m^2: 72 (29.5%); 30 to 39 kg/m^2: 50 (20.5%); 40 kg/m^2 or greater: 18 (7.4%). There was no difference in ISS among BMI class. Similarly, the distributions of pelvic and acetabular fractures were not significantly different nor were combined pelvic/acetabular injuries more common in one BMI class compared with another (Table 2). There was no difference in transfusion in patients with a normal BMI (less than 25 kg/m^2) (21.2 *vs* 31.4%; $P = 0.07$). In patients with BMI 40 kg/m^2 or greater, there was a significant difference in the percentage of patients who received transfusion (55.6 *vs* 24.8%; $P = 0.005$) and the total amount of blood transfused (2.2 ± 2.9 *vs* 1.0 ± 2.2 mL; $P = 0.04$) when compared with the rest of the population with BMI less than 40 kg/m^2. Distribution of RBC transfusion by BMI class is depicted in Table 3. There was no difference in admission hematocrit (38.1 ± 5.5 *vs* 35.1 ± 4.8, $P = 0.14$), ED systolic blood pressure (144 ± 32.4 *vs* 125.9 ± 17.8 mmHg, $P = 0.08$), or ED pulse (102.2 ± 17.5 *vs* 95.9 ± 16.0 beats/min, $P = 0.23$) among morbidly obese patients who received blood compared with patients who were not morbidly obese and received blood. There was no difference in morbidly obese patients who underwent operative intervention within 24 hours compared with morbidly obese patients who underwent fixation greater than 24 hours (11.1 *vs* 22.6%, $P = 0.26$).

A multivariable logistic regression model testing the effect of morbid obesity on the frequency of transfusion was evaluated after adjusting for the confounding variables age, fractures "likely to receive

TABLE 3. *Blood Transfusion Rates*

	Transfused (n = 66)	Not Transfused (n = 178)	*P* Value
Age (years) (SD)	45.4 (18.8)	36.1 (16.1)	0.0002
Male sex, no. (%)	44 (66.7)	126 (70.8)	0.53
ISS (SD)	12.8 (3.9)	12.8 (4.6)	0.93
Fracture "likely to receive transfusion," no. (%)	53 (80.3)	89 (50.0)	<0.0001
Combined pelvic/acetabulum, no. (%)	18 (27.3)	13 (7.3)	<0.0001
BMI class (kg/m^2), no. (%)			0.01
<25	22 (33.3)	82 (46.1)	
25–29.9	23 (34.9)	49 (27.5)	
30–39.9	11 (16.7)	39 (29.1)	
≥40	10 (15.2)	8 (4.5)	

ISS, Injury Severity Score; SD, standard deviation; BMI, body mass index.

transfusion," and combined pelvic/acetabular fractures. Results demonstrated that age (OR, 1.0; 95% CI, 1.01 to 1.05), fractures "likely to receive transfusion" (OR, 2.8; 95% CI, 1.5 to 5.3), and combined fractures (OR, 3.8; 95% CI, 1.6 to 9.1) were retained in the final model. Moreover, BMI 40 kg/m^2 or greater conferred the greatest risk for posttraumatic transfusion (OR, 4.1; 95% CI, 1.4 to 12.0) after adjusting for potential confounders. A second multivariable regression model was then constructed investigating the contribution of morbid obesity to blood transfusion after adjusting for age and fractures considered "less likely to receive transfusion." Testing revealed that morbid obesity (BMI 40 kg/m^2 or greater) remained a significant risk factor for transfusion (OR, 4.5; 95% CI, 1.5 to 12.9) even after adjusting for fractures "less likely to transfuse" (OR, 0.29; 95% CI, 0.15 to 0.53).

Discussion

Increasing morbidity associated with elevated BMI is not a new concept in trauma patients.[4, 8, 10–12] Multiple publications demonstrate the greater risk of morbidity after operative fixation of pelvic[10, 12] and acetabular[8, 11] fractures in patients with an elevated BMI. Few studies, however, have investigated the effect of BMI during the immediate postinjury and resuscitation period in patients with pelvic injuries.[2, 6, 27] We therefore conducted this study to evaluate the relationship of BMI and posttraumatic transfusion in patients with isolated pelvic and acetabular fractures.

Significant bleeding and hemodynamic instability is not uncommon after high-energy pelvic trauma.[28–30] Resuscitation efforts require prompt assessment to direct appropriate diagnostic and treatment priorities.[28] Magnussen and colleagues[18] evaluated the transfusion requirements of isolated pelvic and acetabulum fractures and established that these patterns of injury were more likely to result in transfusion. They also concluded that injuries with concomitant pelvic and acetabulum fractures were more likely to require blood transfusion than a pelvic or acetabular injury alone. This result was also confirmed in a study by Suzuki et al.[25] Previous studies investigating hemorrhage after severe pelvic injuries report that the magnitude of bleeding in multiple trauma patients is best predicted by injury severity.[30, 31] Extrapolation of such conclusions from a multiple trauma population in an attempt to correlate bleeding with pelvic or acetabulum fracture pattern is complicated because hemorrhage from other sources (i.e., long-bone fractures) may be difficult to quantify. The present study population included patients without severe concomitant injuries so as to clearly identify the source of potential bleeding from pelvic injury. ISS was not associated with a greater likelihood to require transfusion in our analysis.

The relationship of BMI to severity of traumatic injury has been investigated in the literature.[9, 32] In a series of trauma patients, Arbabi and colleagues[9] demonstrated that for a given ISS, there were less severe abdominal and pelvic injuries in patients with a BMI 30 kg/m^2 or greater. The authors suggested that obese patients sustain different injury patterns after severe blunt trauma than nonobese counterparts. The term "cushion effect" described the protection that may be afforded because of an increase in insulating abdominal tissue that is present in obese individuals. Understanding the impact of BMI on the relationship to high-energy pelvic injury is of considerable interest to practitioners who are involved with the initial injury management. Our results demonstrate that a lower BMI is not associated with transfusion. Rather, morbidly obese patients with pelvic and acetabular fractures were at increased risk for transfusion.

Morbid obesity presents an array of challenges in evaluating and managing severely injured patients. Greater amounts of soft tissue or intra-abdominal gas may obscure the osseous anatomy in radiographic images.[26, 33] Furthermore, weight restrictions on CT scan tables and difficulties with transfer and routine nursing care are a concern in obese individuals.[11, 33] Even rapidly accessible modalities to assess for intra-abdominal and pelvic fluid such as diagnostic peritoneal lavage or ultrasound may be more difficult in patients with elevated BMI. Studies demonstrated that traditional measures of adequate resuscitation in morbidly obese trauma victims do not provide as useful information compared with nonobese patients.[27] The authors concluded that suboptimal posttraumatic resuscitation is likely common in the morbidly obese population. Identifying and correcting a potential source of blood loss is paramount to resuscitation efforts in patients with pelvic trauma.[28]

There are several limitations to this study that deserve consideration. This retrospective evaluation was conducted at a single institution and contains inherent bias associated with such investigations. The issues associated with retrospective calculation of BMI and potential self-reported measures are discussed in previous publications in the trauma literature and may actually underreport the prevalence of morbid obesity.[11, 34] Geographic location may certainly play a role as well. We documented that 7 per cent of our patient population was morbidly obese, which is lower than previous reports from the literature describing postoperative complications after pelvic[10, 12] and acetabular[8, 11] fractures but similar to publications that examined the effect of BMI in critically ill patients.[26] Furthermore, the prevalence of morbid obesity in our study closely resembles what is reported in the U.S. population.[35, 36] The sample size of morbidly obese patients in this study should also be closely scrutinized, because this has been described as a weakness of other publications investigating BMI.[6] However, analysis demonstrates that our study is able to detect with 71 per cent power that the difference in transfusion rate between morbidly obese patients and the rest of the population is a true difference.

We also included only blood transfusions, which occurred before early operative intervention. Previous studies have reported differing results with regard to intraoperative blood loss and transfusion in morbidly obese pelvic fractures[8, 10, 11] and in patients who underwent early fracture fixation.[37] The hypothesis of the present study was that morbidly obese patients were less likely to receive a transfusion in the immediate posttraumatic period and we sought to exclude any transfusion that may have resulted from operative blood loss. Although there were no differences in transfusion among patients who underwent early fixation nor were obese patients more likely to receive fracture care greater than 24 hours, interpretation of this data should proceed with caution. Lastly, as a result of the retrospective nature of this study, we are not able to provide well-defined criteria for when blood transfusion was initiated during the first 24 hours of hospital presentation. This has been discussed in detail in previous literature describing bleeding rates after pelvic injury.[18] We are able to comment that the decision to transfuse was made at the discretion of a fellowship-trained attending general surgery traumatologist in accordance with the patient's overall physiologic and laboratory parameters and the principles of Advanced Trauma Life Support.[38]

Recognition of severe injury and certain patient characteristics, which incur greater risk for blood transfusion, is of significant importance. Our study involved a very unique population of pelvic and acetabular injuries to quantify potential bleeding from these sites of injury. Although we cannot further comment on other aspects of the "cushion effect" such as redistribution of injuries to other body regions,[9, 32] this study does provide information to suggest that morbid obesity is a risk factor for posttraumatic transfusion requirements in patients with pelvic injuries. Perhaps even more striking is the result that morbid obesity remains a significant risk factor for transfusion even after adjusting for pelvic and acetabular fracture patterns that are demonstrated to be "less likely to receive transfusion." Recent trends of the obesity epidemic highlight a growing problem facing both the patient and treating physicians. Prompt attention to life-threatening conditions and consideration of factors that will affect management of injuries are valuable to the multidisciplinary approach of patients with severe pelvic injuries. We acknowledge that certain patient variables are out of the control of the treating surgeon; however, understanding the role and impact of such characteristics in treatment algorithms may potentially identify those patients at greatest risk for posttraumatic transfusion.

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