Assessing the Relationship Between BMI and Resource Utilization in a Pediatric Trauma Population

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In 2000, 15.5% of children surpassed the BMI for age at the 95th percentile; in 2010, this percentage increased to 16.9%. Children with higher BMIs are at an increased risk for developing cardiovascular, endocrine, and mental disorders and may suffer more from diseases such as asthma and obstructive sleep apnea. Even more concerning is that approximately one-half of obese school-aged children become obese adults who are then at risk for diseases associated with adulthood obesity. The cost of treating adult obesity and its related comorbidities is significant, with estimates approaching $94 billion per year in 2002. Data related to health care utilization for overweight children are limited; 1 estimate suggests that obesity-associated inpatient hospitalization costs have risen threefold, from $35 million in 1979–1981 to $127 million in 1997–1999.

Trauma is the leading cause of morbidity and mortality for pediatric patients, typically requiring extensive resources and expensive hospital-based health care. Multiple studies have reviewed the association between obesity and trauma outcomes (eg, ICU and hospital length of stay [LOS], mortality), with varied results. Single institutional studies have concluded that obese patients experiencing traumatic injuries have a higher incidence of complications, increased risk for ventilator support, and longer hospitalizations for comparable injury severity scores (ISS) than those with normal BMIs. In contrast, other studies have determined that there are no differences in total ventilation days or PICU LOS and found no association with mortality after adjusting for ISS in obese pediatric patients.

Because hospital resources are finite, current health care economics demand optimal patient care at the lowest cost, appropriate utilization is therefore crucial. For the purposes of hospital planning and management, patient populations requiring more resources must be identified. Cochran et al stated that hospital resource utilization provides an important means of evaluating cost-efficiency in trauma care. However, few studies have been conducted specifically reviewing the association between pediatric trauma and resource utilization. Due to rising obesity rates and the availability of pediatric hospital resources, it is necessary to understand the relationship between patient/injury characteristics (ie, BMI) and hospital resource usage. The primary aim of the present study was to explore if an increase in BMI affects resource usage in a pediatric trauma population.

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METHODS

Settings
A trauma registry was retrospectively analyzed to examine pediatric patients (aged 2–17 years) admitted between 2004 and 2012 at an American College of Surgeons–verified Level II pediatric trauma facility (within an adult-verified Level I facility) in a predominantly rural state. Excluded were patients who were dead on arrival and burn victims (physiologic and clinical factors affecting outcomes differ from other critical care populations). Patients transferred to another acute care facility before 1 week were excluded because their final outcomes are not present in the registry. In addition, patients were excluded if they had missing anthropometric data (height, weight, or BMI). Approval was obtained from all appropriate institutional review boards.

Defining BMI
Pediatric patients (aged 2–17 years) were grouped according to their BMI, calculated by using the following equation: BMI = weight (kilograms)/height (meters squared). Each patient’s height and weight were used if not registry calculated. The BMI percentile was determined according to published charts for age and gender. Patients were first stratified into 4 groups (underweight [BMI for age <5th percentile], healthy weight [BMI for age fifth to <85th percentile], overweight [BMI for age 85th to <95th percentile], and obese [BMI for age ≥95th percentile]) based on gender-specific BMI for age growth charts. This classification resulted in few significant differences in population demographic characteristics or resource utilization outcomes among the 4 groups. Patients were therefore further stratified into nonobese (<95th percentile) and obese (≥95th percentile) groups.

Study Variables
Demographic and clinical data were extracted from the trauma registry; the variables undergoing univariate analysis included gender, mechanism of injury, Glasgow Coma Scale, mortality, and discharge destination. The selection of variables for multivariate analyses was based on availability as well as on variables of interest. Patient/injury characteristic variables included BMI (the outcome of interest, shown to be associated with resource usage), age (associated with trauma outcomes, ISS (shown to be associated with resource usage) and trauma outcomes), and physiologic complications (a measure of injury severity, which researchers hypothesized would be related to resource usage due to increased complications [cardiac and pulmonary] for obese patients). Hospital resource usage variables included ICU LOS and hospital LOS (both of which have been observed in the literature as measures of resource utilization). Medical consults (eg, neurosurgery, orthopedics [to assess “human resources”]), and procedures (eg, computerized axial tomography, splint extremity [to assess “human” and material resources]). Due to the highly skewed nature of ICU LOS and hospital LOS, a log transformation was performed for multivariate analysis. The selection of variables was exploratory because an analysis of this complexity concerning resource usage has not been conducted.

Statistical Analysis
The primary outcome of interest was resource usage, including hospital LOS and ICU LOS, total medical consults, and total procedures; the secondary outcome was mortality. Descriptive statistics were summarized by using frequencies (percentages), means ± SDs, and medians (interquartile ranges). Continuous variables were compared by using Kruskal-Wallis tests (nonparametric analysis of variance) and Mann-Whitney tests (nonparametric t test); categorical variables were analyzed by using \( \chi^2 \) tests. Statistical significance was set at \( P < .05 \). Statistical analysis was performed by using SPSS for Windows version 20.0 (IBM SPSS Statistics, IBM Corporation, Armonk, NY).

Canonical correlation analysis is an exploratory multivariate statistical analysis of the correlation between 2 separate and distinct sets of variables. Every patient is measured on each set of variables (patient/injury characteristic variables and hospital resource usage variables) to determine the dimensions in which the variables are related. The optimal linear combination of 1 set of variables (a canonical variate) are combined to produce, on each side, a predicted value that has the highest correlations with the predicted value on the other side (forming a pair of canonical variates). Canonical loadings (correlation values) are produced to measure the relationship between every observed variable and its canonical variate (composite). This statistical analysis can also be considered as creating multiple composite variables. In the present study, the individual variables (age, BMI, ISS, and total physiologic complications) represent the first composite variable (patient/injury characteristics), and the individual variables (ICU LOS, hospital LOS, total medical consults, and total procedures) represent a second composite variable (hospital resource usage). The analysis determines the relationship between the 2 composite variables.

RESULTS
Of the 1620 pediatric study patients in the final sample, 82.2% (\( n = 1332 \)) were nonobese and 17.8% (\( n = 288 \)) were obese (Table 1). The majority (61.9% (\( n = 1003 \))) were male, and 90.6% (\( n = 1450 \)) were white. The mean ± SD age was 11.38 ± 5.07 years. The mean ISS was 9.79 ± 5.34. The most common mechanism of injury was “other” (eg, sports injury, off-road vehicle) (43.6%), followed by motor vehicle crash (34.9%) and falls (21.5%). The majority (97.4%) of patients survived.

There were no statistically significant differences between nonobese and obese patients for total procedures (3.15 vs 3.12; \( P = .911 \)), total medical consults (1.02 vs 1.07; \( P = .333 \)), days in the ICU (1.15 vs 1.18 days; \( P = .291 \)), and days in the hospital (2.04 vs 1.92 days; \( P = .909 \) (Table 1). The majority (93.2%) of patients were discharged from the hospital, 5.7% to continued care, and 1.1% to “non-home” (eg, mental health facility, other acute care hospital). No
univariate significant differences in in-hospital mortality were observed between nonobese and obese patients (2.3% vs. 4.2%; \(P = .064\)). Compared with survivors, nonsurvivors were older (15 vs 13 years; \(P = .026\)), had a higher BMI (22 vs 20.1; \(P = .031\)), higher ISS (32 vs 6; \(P < .001\)), more total physiologic complications (1 vs 0; \(P < .001\)), longer ICU LOS (1 vs 0 days; \(P < .001\)), shorter hospital LOS (1 vs 2 days; \(P < .001\)), more total medical consults (2 vs 1; \(P < .001\)), and more total procedures (7 vs 2; \(P < .001\)) (Table 2).

**Canonical Correlation Analysis**

A graphical model of the canonical correlation analysis is depicted in Fig 1. This analysis indicates that the first canonical correlation pair was significant (\(r = 0.79\), accounting for 62% variance); there was a significant linear association between patient characteristics and resource utilization. Using the 0.30 correlation cutoff suggested by Tabachnick and Fidell,\(\text{31}\) correlations for ISS (0.49) and total physiologic complications (0.68) were associated with hospital resource usage. In the second variable set, correlations for hospital LOS (0.51) and total procedures (0.56) exceeded the cutoff level. This finding indicates that when using the first pair of canonical variates, as ISS and physiologic complications increased, a patient spent more days in the hospital and underwent more procedures. There was no relationship between BMI and hospital resource usage in this sample.

**DISCUSSION**

The present exploratory study sought to examine the relationship between patient/injury characteristics and hospital resource usage according to canonical correlation analysis. Within this pediatric population, the association between BMI and mortality could not be determined, and there was no association between BMI and hospital resource usage. The more severely injured patients had longer hospital LOS and underwent more procedures. There was no association between age or BMI for patient characteristics or ICU LOS or medical consults for resource usage. The univariate analysis found significant differences in patient/injury characteristics and resource usage between survivors and nonsurvivors, and it also determined that nonsurvivors should be analyzed separately. Furthermore, the sample size of nonsurvivors (2.6% \(n =\)
our findings are novel in that they are both consistent and inconsistent with previous research. The majority of previous studies assessing BMI in the pediatric population (typically comparing obese with other classifications) examined only 1 aspect of hospital resource usage independently (i.e., ventilator days, hospital LOS). Brown et al15 examined outcomes including need and length of mechanical ventilation, complications, hospital LOS and ICU LOS, and mortality. Although the ISS were similar for obese and nonobese subjects in their study sample, obese children had more complications and longer ICU LOS compared with nonobese children. Brown et al suggested that subsequent studies are required to understand why obese patients fare worse in terms of trauma. Similar to Backstrom et al,17 this study determined, via a multivariate analysis, that injury severity rather than BMI was associated with patient resource utilization. It was consistent with several other studies which have found that ISS rather than obesity has the greatest influence on poor outcomes.17–19

Although the present study was not a comprehensive measure of resource usage (but rather an exploratory method), information can be gleaned from the results to enhance our understanding of the complexity of patient outcomes. The study concluded that there was no association between BMI and hospital resource usage. There has been very little in the literature concluding what the effect of BMI on resource utilization means in terms of trauma services. In this sample, BMI did not seem to affect trauma resource utilization and therefore would not warrant planning changes to pediatric program management. One explanation for this finding could be that obesity is not a physiologic factor associated with resource usage once assessed with multivariate methods. Additional determinants associated with obesity (e.g., comorbidities) may be the underlying difference rather than obesity itself. Another explanation could be that the American College of Surgeons–verified Level II pediatric trauma system is adequate to handle the patients. Additional multivariate analyses could be performed to ascertain which factors are most influential.

### Table 2: Mann-Whitney Median Testing Test for Survivors and Nonsurvivors

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Survivors (n = 1578 [97.4%])</th>
<th>Nonsurvivors (n = 42 [2.6%])</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>13 (9)</td>
<td>15 (7)</td>
<td>.026</td>
</tr>
<tr>
<td>BMI</td>
<td>20.1 (6.6)</td>
<td>22 (9)</td>
<td>.031</td>
</tr>
<tr>
<td>ISS</td>
<td>6 (8)</td>
<td>32 (13)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Total physiologic complications*</td>
<td>0 (0)</td>
<td>1 (2)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>ICU LOS, d</td>
<td>0 (1)</td>
<td>1 (2)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Hospital LOS, d</td>
<td>2 (2)</td>
<td>1 (3)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Total medical consults*</td>
<td>1 (2)</td>
<td>2 (1)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Total procedures*</td>
<td>2 (3)</td>
<td>7 (5)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Data are presented as median (interquartile range). Mann-Whitney testing was completed.


† Total medical consults include: allergy/immunology, anesthesiology, neurosurgery, neurology, orthopedics, pediatric medicine, cardiology, ear, nose, and throat specialist, emergency medicine, trauma surgery, family practice, general surgery, hand/orthopedic surgery, internal medicine, burn care specialist, ophthalmology, oral and maxillofacial surgery, renal, vascular surgery, physical medicine/rehabilitation, urology, obstetrics and gynecology, psychiatry, plastic surgery, infectious disease, pulmonary, radiology, thoracic surgery, other.

‡ Total procedures include but are not limited to: computerized axial tomography, electrocardiogram, echocardiogram, splint extremity, excisional debridement of wound, infection, or burn, endotracheal intubation, MRI, skin suture.

### Figure 1: Canonical Loadings between Patient Characteristics and Resource Usage Variables and their Corresponding Canonical Variates

- **Age**: 0.04
- **BMI**: 0.03
- **ISS**: 0.49
- **Total physiological complications**: 0.68

**Calculations**

**Correlation coefficient (r)**: 0.79

**Significance test for canonical correlation**: \( \chi^2(16) = 53.65, P < .001 \).
mitigate adverse outcomes for obese pediatric patients. These centers may be better equipped to provide appropriate care to offset the impact of obesity. Outcome differences may be apparent in nontrauma centers that are not adequately prepared to care for such patients.

The present analysis was completed solely in a trauma population; however, the metrics used to assess resource usage included hospital factors that spanned the stay for patients (eg, hospital LOS, procedures, physiologic complications). The critically injured population was assessed due to the resource-intensive nature of their trauma. Their injuries are often complex and require a wide range of hospital resources and clinical expertise across multiple departments within the hospital. An evaluation of hospital resources can begin there with this resource-intensive division for the effective designation of resources.

The present study found that within our pediatric trauma population, injury factors (rather than patient characteristics [eg, age, BMI]) influence hospital resource utilization. Although the association between injury severity and outcomes has been well documented, the association between patient factors and outcomes has not been explored in the same manner. Researchers, however, acknowledge the limitations associated with variables included in analysis and recognize that other variables should be assessed to determine the full scope of resource utilization. To provide appropriate care and improve care processes, information concerning resource utilization among specific populations should be analyzed. This project offers additional insight into the relationship of the patient and the necessary resources to provide optimal patient care to pediatric trauma patients.

In addition, consideration of mortality as an end point in this population should be critically evaluated. We were unable to ascertain the effects of BMI on mortality via a multivariate analysis. Our study included 42 (2.6%) in-hospital mortalities from 1620 total patients. To appropriately conduct a statistical analysis and arrive at accurate conclusions, proper sample size calculations must be completed and assumptions met. Although several studies have examined mortality as an outcome, the statistical methods of those studies may be inaccurate. This statistical dilemma can occur with most studies involving pediatric patients. We therefore propose that mortality is not an appropriate end point for a pediatric population.

Limitations

The present study used data from the trauma registry, which is not designed specifically for research purposes. Therefore, incomplete and missing data (specifically, missing anthropometric data) may have led to a potential bias in this population. Conclusions drawn from the results are specific to our data set and may not be generalizable to other trauma populations. Furthermore, although practice guidelines are developed to meet the current American College of Surgeons review book, they are facility-specific and could bias findings.

In addition, other factors might influence hospital resource utilization that are not accounted for in this analysis (eg, comorbidities). However, due to the incomplete nature of this variable in our registry, we were unable to control for the effects of the type and number of comorbidities. Additional patient factors, injury factors, and hospital resource usage variables that affect one another were not included in the analysis due to availability, high correlation with other variables, and the exploratory nature of the study.

Future Research

Future research should explore the multifaceted approach to understanding hospital resource usage in terms of LOS, procedures, complications, comorbidities, ventilator days, and human resources. Multivariate analyses are useful in assessing multiple outcome variables and offer a complexity to studies in which outcomes coincide in reality. Development of a composite weighted variable with which to assess and standardize hospital resource usage via multivariate analysis would be ideal to accurately gauge utilization among a trauma population and hospital-wide. To take into account financial resource utilization, cost should also be included in future analyses. Additional resources “consumed” postdischarge (eg, care provided by caregivers, rehabilitation, medicinal needs) are necessary to fully understand resource utilization.

Future researchers should also compile a nonsurvivor sample large enough to assess differences in resource usage compared with survivors. Within our analysis, we found that the outcomes for survivors and nonsurvivors were significantly different, and we did not include nonsurvivors in the data analysis. However, although nonsurvivors died during the course of care, they did consume hospital resources during their stay. There may be additional patient and injury factors that influence nonsurvivor resource usage differently from survivors, and these factors should be investigated in a larger population.

CONCLUSIONS

This study found that BMI was not associated with resource usage. Injury severity, as assessed in terms of ISS and physiologic complications, was associated with hospital resource usage (increase in hospital LOS and total procedures). The relationship between BMI and mortality was unable to be assessed due to sample size limitations. Given these results, hospital resource usage should be considered as a composite outcome variable of interest rather than viewed as a single outcome. Furthermore, mortality may not be the most effective end point when evaluating pediatric BMI, given the small percentage of pediatric patients across studies who die. This study provides valuable information concerning the impact of patient/injury characteristics in a pediatric trauma population and the utilization of hospital resources.

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REFERENCES