Obesity and outcomes following burns in the pediatric population

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ABSTRACT

Purpose: While obesity is associated with increased mortality and decreased functional outcomes in adult burn patients, the ramifications of larger than average body size in the pediatric burn population are less well understood. The present study examines whether obesity was associated with poor outcomes following pediatric burn injuries.

Methods: Thermal injury data for patients ≤18 years of age admitted to a Level III burn center over ten years (n = 536) was analyzed. Obesity was defined as ≥95th percentile of weight for height according to the WHO growth charts (<2 years of age) or BMI for age according to the CDC growth charts (2–18 years of age). Outcomes were compared between thermally injured obese (n = 154) and non-obese (n = 382) children. All data was collected in accordance with IRB regulations.

Results: Obese and non-obese thermally-injured children did not differ in TBSA, percentage of full thickness burn, or overall mortality. However, these groups were significantly different with respect to age (obese = 7.16 ± 0.46 years, non-obese = 9.38 ± 0.32 years, p < 0.001) and days requiring mechanical ventilation (obese = 4.89 ± 1.3 days, non-obese = 2.67 ± 0.49 days, p < 0.05). For thermally injured children admitted to the BICU without inhalation injury (n = 175), the obese (n = 46) and non-obese (n = 129) did not differ significantly with respect to age, TBSA, percentage of full thickness burn or other outcome measures. However, significant differences between these groups were noted for ICU LOS (obese = 18.59 ± 5.18 days, non-obese = 9.51 ± 1.82 days, p < 0.05) and number of days requiring mechanical ventilation (obese = 11.65 ± 3.91 days, non-obese = 3.92 ± 0.85 days, p < 0.05).

Conclusion: These data show thermally-injured obese pediatric patients required longer and more intensive medical support in the form of BICU care and respiratory intervention. Counter to findings in adult populations, differences in mortality were not observed. Collectively, these findings suggest obesity as a risk factor for increased morbidity in the pediatric burn population.

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Obesity and related co-morbidities (diabetes, hypertension, respiratory and cardiac insufficiency), predispose to surgical and post-injury complications not encountered by non-obese individuals [1,2]. Outcomes of severe thermal injury, traditionally determined by age, injury severity and inhalation injury are also influenced by body habitus [3,4]. In adults, obesity is associated with higher than predicted rates of bacteremia, sepsis, pneumonia, length of stay and ventilator days, as well as overall burn-related mortality [5]. With 32% of the American adult population classified as obese, the treatment and outcomes of burn injury has been significantly affected. Management of the morbidly obese patient is complicated by their anatomy, physiology and metabolism and requires significant technical expertise, especially in critical care management [6,7].

Mortality from severe thermal injury in the pediatric population has been shown to be related to age, burn size, presence of inhalation injury, delayed resuscitation, anemia, sepsis, thrombocytopenia, hyperosmolarity, and ventilatory dependence [8]. Currently, 30% of individuals younger than 18 years of age are considered overweight, while 16% are estimated to be obese [9]. Despite a direct correlation between obesity and poor outcomes of non-burn pediatric trauma, the implications of obese body habitus in thermally injured children are less well defined [10]. The aim of this study was to determine the morbidity and potential mortality associated with obesity on the care of post-burn pediatric patients.

1. Methods

Data on patients ≤18 years of age who were admitted to a large regional burn unit between the years of 2000 and 2010 and for whom height and weight data was available (n = 571) was collected from the hospital’s burn database. Obesity was defined as ≥95th percentile of weight for height according to the World Health Organization growth charts for children <2 years of age. For children 2–18 years of age, body mass index (BMI = weight[kg]/height 2[m 2]) for age according to the Centers for Disease Control growth charts was

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utilized to determine obesity. Demographic, burn-related data and outcome parameters were compared between thermally-injured children classified as obese and those classified as non-obese. Demographic data considered included age, gender, height and weight. Burn-related data considered were TBSA, percentage full thickness burns, presence of inhalation injury, and proportion of patients requiring ICU admission. Outcome parameters examined were overall mortality, days in ICU, days requiring mechanical ventilation, total hospital length of stay, incidence of sepsis, number of operations required, courses of antibiotics prescribed, and the number of lung, blood and wound cultures positive for pathogens. Thirty-five patients were excluded (10/164 obese and 25/407 non-obese) for non-thermal cutaneous injury.

All patients upon admission for burn wound care had a full assessment of the airway and cutaneous injury undertaken, and the percentage of total body surface area (TBSA) involved was calculated. Pre-resuscitation height and weight were measured and recorded. All patients were resuscitated, if required, according to the Parkland formula, (4 cc/kg/%TBSA of lactated Ringers solution) to achieve a urine output of approximately 1 cc/kg/hour. Upon arrival all cutaneous thermal wounds were débrided, covered with topical antibacterial agent (silver sulfadiazine) and steriley dressed. Long-term ward or Burn Intensive Care Unit (BICU) fluid management strategies, nutritional support (enteral soy-based formulas initiated within 48 hours of injury), and surgical interventions (early burn wound excision with auto/homograft/dermal substitute coverage) were instituted uniformly according to established institutional protocols and treatment algorithms. Similarly, pulmonary protocols (frequent pulmonary toilet; deep airway suctioning; CPT procedures, albuterol nebulizer treatments; etc), as well as ventilator strategies in the BICU (pressure control ventilation; PEEP; low tidal volume; FiO2; etc) were uniformly instituted as required. This study was reviewed, approved by and conducted in accordance with guidelines of the local institutional review board.

2. Statistics

Results are expressed in Tables 1, 2, and 3 as either mean values with associated standard errors or as proportions as appropriate. The differences between means were assessed for significance using unpaired, two-tailed Student’s t-tests, while the differences between proportions were assessed for significance using chi-squared tests. In all cases, a p-value of less than 0.05 was considered significant.

3. Results

The obese (n = 154) and non-obese (n = 382) cohorts of thermally-injured children did not differ significantly with respect to TBSA, percentage of full thickness thermal injury, presence of inhalation injury, or ICU admission requirement. The two groups showed no difference in overall mortality, incidence of sepsis, length of hospital stay, length of ICU stay, number of operative procedures, number of positive blood cultures, number of positive wound cultures (Table 1). Non-obese children were significantly older and predominantly male, while the obese group required significantly longer mechanical ventilator support and had higher incidence of lung cultures positive for pathogens (i.e., *Staphylococcus*, *MRSA*, *Enterobacter*, *Candida*, other fungus and *Haemophilus*). When subjected to univariate linear regression analysis, neither age nor gender was found to be significantly related to days of mechanical ventilation or to number of positive lung cultures. While non-obese children showed a tightly clustered range of BMI around the mean for each age group, obese children showed a greater range of BMI for each age (Fig. 1).

Of all children requiring Burn Intensive Care Unit (BICU) admission (n = 205), obese children (n = 55) had a significantly longer ICU length of stay, longer requirement for ventilator support, a higher incidence of positive lung cultures, and required more courses of antibiotics than their non-obese counterparts (n = 150) (Table 2). However, these groups did not differ significantly with respect to age, gender, TBSA, percentage of full thickness thermal injury, presence of
inhalation injury, total length of hospital stay, incidence of sepsis, number of operative procedures, number of positive lung cultures, number of positive blood cultures, or overall mortality. Thirty patients were treated for concomitant cutaneous thermal injury and smoke inhalation. There was no significant difference in the incidence of smoke inhalation injury between obese and non-obese children admitted to BICU. When burn-injured children with concomitant smoke inhalation injury were omitted from the overall BICU cohort, obese children (n = 46) were found to require a longer BICU stay, needed more days of ventilator support, had a higher incidence of positive lung cultures, and required more courses of antibiotic treatment than their non-obese (n = 129) counterparts (Table 3).

When considering other comorbidities, such as asthma, chronic lung disease, or other chronic medical illness, as possible causes for the increased ICU days and mechanical ventilation the database was assessed regarding pre-burn diagnoses insofar as they are known for each patient. Using a chi-squared analysis, no difference in the prevalence of asthma was found between the obese and non-obese cohorts ($\chi^2 = 16$, $p = 0.69$), between the ICU cohorts ($\chi^2 = 0.0043$, $p = 0.95$), nor between the ICU cohorts with inhalation injuries excluded ($\chi^2 = 0.11$, $p = 0.74$). Other injuries, including non-accidental trauma and musculoskeletal injury for the obese and non-obese cohorts were examined via chi-squared test. Abuse prevalence was not different between the two groups overall ($\chi^2 = 0.44$, $p = 0.51$), between the ICU cohorts ($\chi^2 = 1.33$, $p = 0.29$), nor between the ICU cohorts with inhalation injuries excluded ($\chi^2 = 1.26$, $p = 0.26$). The prevalence of musculoskeletal injuries in addition to the burn injury was analyzed using a chi-squared test. No difference was found between the obese and non-obese cohorts overall ($\chi^2 = 0.0030$, $p = 0.96$), between the two ICU cohorts ($\chi^2 = 0.083$, $p = 0.77$), nor between the ICU cohorts with inhalation injuries excluded ($\chi^2 = 0.088$, $p = 0.77$).

The prevalence of patient transfers from outside facilities was compared between the obese and non-obese cohorts using a chi-squared test. There was no difference between the groups overall ($\chi^2 = 0.052$, $p = 0.82$), between patients admitted to the ICU ($\chi^2 = 0.018$, $p = 0.89$), nor between patients admitted to the ICU without inhalation injuries ($\chi^2 = 0.089$, $p = 0.77$).

The etiology and anatomic location of the burn injuries were compared between the two groups using chi-squared tests. The obese group had a lower prevalence of gas-accelerated burns than the non-obese group ($\chi^2 = 4.31$, $p = 0.038$) while neither group had a higher prevalence of burns to the face than the other ($\chi^2 = 0.00075$, $p = 0.98$). Univariate linear regression demonstrated no significant relationship between gas-accelerated burns and ventilator days.

### Table 3

<table>
<thead>
<tr>
<th></th>
<th>Obese (46)</th>
<th>SEM</th>
<th>Not Obese (129)</th>
<th>SEM</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)*</td>
<td>6.70</td>
<td>0.78</td>
<td>8.62</td>
<td>0.55</td>
<td>0.066</td>
</tr>
<tr>
<td>Height (inches)*</td>
<td>45.67</td>
<td>2.38</td>
<td>51.02</td>
<td>1.35</td>
<td>0.05</td>
</tr>
<tr>
<td>Weight (kilograms)*</td>
<td>41.87</td>
<td>4.23</td>
<td>34.88</td>
<td>2.11</td>
<td>0.11</td>
</tr>
<tr>
<td>Proportion maleb</td>
<td>78.3%</td>
<td></td>
<td>76.0%</td>
<td></td>
<td>0.75</td>
</tr>
<tr>
<td>Total burned surface area (%)b</td>
<td>26.28</td>
<td>3.26</td>
<td>25.78</td>
<td>1.53</td>
<td>0.88</td>
</tr>
<tr>
<td>Full thickness (%)a</td>
<td>10.87</td>
<td>2.85</td>
<td>11.16</td>
<td>1.64</td>
<td>0.93</td>
</tr>
<tr>
<td>Sepsisb</td>
<td>8.70%</td>
<td></td>
<td>3.10%</td>
<td></td>
<td>0.25</td>
</tr>
<tr>
<td>Mortalityb</td>
<td>2.17%</td>
<td></td>
<td>2.33%</td>
<td></td>
<td>0.61</td>
</tr>
<tr>
<td>Mechanical ventilation (days)*</td>
<td>11.65</td>
<td>3.91</td>
<td>3.92</td>
<td>0.85</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>Total length of stay (days)*</td>
<td>26.17</td>
<td>5.44</td>
<td>17.88</td>
<td>2.14</td>
<td>0.088</td>
</tr>
<tr>
<td>Total ICU stay (days)*</td>
<td>18.59</td>
<td>5.18</td>
<td>9.51</td>
<td>1.82</td>
<td>p &lt; 0.05</td>
</tr>
<tr>
<td>Number of positive lung culturesa</td>
<td>1.00</td>
<td>0.27</td>
<td>0.35</td>
<td>0.074</td>
<td>p &lt; 0.05</td>
</tr>
<tr>
<td>Number of positive wound culturesa</td>
<td>0.39</td>
<td>0.18</td>
<td>0.21</td>
<td>0.065</td>
<td>0.23</td>
</tr>
<tr>
<td>Number of positive blood culturesa</td>
<td>0.20</td>
<td>0.10</td>
<td>0.11</td>
<td>0.042</td>
<td>0.35</td>
</tr>
<tr>
<td>Operationsa</td>
<td>1.98</td>
<td>0.55</td>
<td>1.36</td>
<td>0.22</td>
<td>0.21</td>
</tr>
<tr>
<td>Units of blood transfuseda</td>
<td>5.13</td>
<td>1.86</td>
<td>2.35</td>
<td>0.59</td>
<td>0.063</td>
</tr>
<tr>
<td>Courses of antibioticsa</td>
<td>1.85</td>
<td>0.37</td>
<td>0.95</td>
<td>0.15</td>
<td>p &lt; 0.01</td>
</tr>
</tbody>
</table>

* Two-tailed, unpaired Student's t-test.

### 4. Discussion

Few studies have been conducted examining the consequences of obesity in children and critical injury. As might be expected, obesity in pediatric patients is not associated with the usual co-morbid conditions (diabetes mellitus, cardiac insufficiency, atherosclerotic vascular disease, venous stasis, etc) known to contribute to post-injury complications.
morbidity and mortality seen in adult obese populations [11–13]. Also, obese pediatric patients, despite the challenges related to body habitus compared to non-obese age group peers, do not present the same physical problems for caregivers that obese adults do. Intravenous access, airway patency, adequacy of appropriately-sized equipment, presence of sufficient personnel to move individual patients, difficult ambulation/mobilization and limited rehabilitation potential, while significant medical concerns in the obese adult population, are less acute issues with the obese child [5]. However, the impact of obesity on the outcome of a child with significant thermal injury has not been fully evaluated. Our study identifies obesity-associated morbidity complicating the care of pediatric burn injury children.

For children younger than 2 years of age, we defined obesity as ≥ 95th percentile of weight for height according to the World Health Organization growth charts. While there are few studies defining obesity in this age group, children younger than 2 years of age have been shown to have increased mortality, higher rates of hospital admission and longer lengths of stay after injury if ≥ 95th percentile of weight for height [10,14]. That the average age of the obese cohort in our review was younger than the non-obese cohort raises the possibility that observed differences in outcome and morbidity may be due to younger age as opposed to increased body mass. Univariate linear regression demonstrated no significant relationship between age and either ICU days or prolonged mechanical ventilation, variables typically associated with poorer outcome. The lack of a significant correlation suggests that age did not have a meaningful influence on the outcome variables of interest in the present analysis.

Our data demonstrate that obese burn-injured children, despite demographic and injury characteristics similar to a non-obese cohort, experienced a more complicated hospital course compared to their non-obese counterparts. Despite a more complicated clinic course, overall length of hospital stay was similar for both obese and non-obese groups. This observation contradicts a recent study which demonstrated approximately 6% increase in overall length of hospitalization associated with obesity for burn-injured children [10]. Our observed lack of difference in hospital stay between groups is likely related to the relatively small mean TBSA burn size, low percentages of full thickness injury and a moderate number of children with concomitant inhalation injuries in both groups. Overall mortality in our study was unrelated to age, burn size, obesity, BICU stay or ventilatory requirements. However, with few deaths in either group (obese 1/non-obese 6), meaningful mortality comparisons between obese and non-obese burn-injury children were not possible. However, a lack of any effect of childhood obesity on post-burn mortality has been previously demonstrated [15]. While we observe no difference in mortality in children with relatively small thermal injuries, this previous work demonstrated no effect of pediatric obesity on post-burn mortality with much average larger thermal injuries (obese: 56% TBSA/40% full thickness and non-obese: 55% TBSA/37% full) than recorded here. In another study, younger age, deeper injury, smoke inhalation, and resultant respiratory failure was associated with 33% burn mortality in obese children [8]. However this degree of mortality was characteristic of a massive burn injury (80% TBSA/70% full thickness) compared to the more modest injury size cited in the current study for obese children.

Burn intensive care unit admission is often required for children with larger TBSA injury and respiratory insufficiency due to smoke inhalation injury. Admissions to our BICU were characterized by larger, more severe thermal injury than in the overall study group; however there was no difference between TBSA burn size and severity (% full thickness) for obese and non-obese children requiring critical care support. Similarly, while thermally injured children requiring BICU admission had a higher incidence of concomitant smoke inhalation, inhalation injury cases were distributed evenly between obese and non-obese children in the BICU as well. In a study of acute phase responses and metabolism in obese children, it was demonstrated inflammatory and metabolic responses are altered by body habitus, suggesting obesity may predispose patients to impaired recovery following thermal injury [15]. Despite this, pediatric obesity did not correlate with an increased incidence of sepsis, multi-organ failure or mortality in pediatric burn patients. Our data demonstrate obese children had higher rates of pulmonary infection, require prolonged ventilator support and have longer BICU stays than their non-obese counterparts. Pulmonary insufficiency after injury in the obese adult patient population is multi-factorial [7]. Poor respiratory mechanics, inadequate ambulation, pulmonary embolism may all contribute to obesity-associated respiratory morbidity and mortality. The higher incidence of respiratory insufficiency in the burn-injured obese children suggests the usual physiological and physical responses required for burn injury recovery may also be impaired or diminished in these children as well.

Pulmonary infections were common in both obese and non-obese BICU groups. Obese children were pulmonary culture positive nearly twice as often as non-obese children after thermal injury. There was a significantly higher incidence of pulmonary pathogens cultured from the lungs of obese children compared to non-obese post-burn counterparts. While increased number of days of mechanical ventilation strongly correlates with pulmonary infection regardless of the causal relationship between the two variables, the significant difference found between the two groups with respect to the number of infections could also indicate a greater susceptibility to infection in the obese; we observed that the number of days spent receiving mechanical ventilation was more strongly correlated with positive lung cultures in the obese cohort than in the non-obese (r = 0.88 vs r = 0.65, p < 0.001). This finding suggests that the increased incidence of pulmonary infection in obese burn-injured children may not simply be due to an increased number of days spent on the ventilator, but rather that obesity predisposes these patients to complex and severe respiratory complications not observed in the non-obese children after thermal injury.

Pulmonary failure from smoke inhalation remains a primary cause of death of patients treated for cutaneous thermal injury [4]. Progressive airway inflammation and edema impair gas exchange and increase the susceptibility to pulmonary infection [16]. In one large adult study, smoke inhalation caused a twofold increase in pneumonia and a fivefold increase in the incidence of acute respiratory distress syndrome (ARDS), both contributing to a mortality rate in this group of 29% compared to 2% in the absence of smoke exposure [17]. To control for smoke inhalation-associated morbidity, we examined data from BICU patients without inhalation injury separately from the overall pediatric BICU population. Obese, burn-injured children without inhalation injury required a longer duration of BICU care, a greater number of days of ventilator support, and a greater number of courses of antibiotics in addition to having a higher incidence of positive lung cultures than their burned non-obese, non-inhalation counterparts. This suggests post-burn pulmonary complications in the obese children were not attributable to smoke inhalation injury and may be related to body habitus. Our observations substantiate those of others showing obesity contributes to a higher incidence of pulmonary infections and persistent post-injury respiratory insufficiency [6,7].

This study’s limitations are typical of large, retrospective reviews. Our conclusions concerning obesity and pediatric burn morbidity are correlative in nature and do not prove causality. Obese and non-obese patients had TBSA burn size and severity of moderate size (<30% TBSA) compared to other published reports. This clearly limits extrapolation of our results to obese children with larger burns. However, a significant cohort that were treated for larger injuries (26–30% TBSA) required BICU support, thus providing a sizable cohort from which to draw conclusions concerning pediatric obesity and burn injury outcomes. As with many database reviews, not all pediatric burn patients admitted for treatment during the study
time period could be included due to missing data. However, those with incomplete data did not differ significantly with regard to demographic factors than those in the final study.

These data demonstrate that thermally-injured obese pediatric patients required longer and more intensive medical support in the form of BICU care, antibiotics and respiratory intervention. In line with the increased requirement for intensive hospital management, obese pediatric patients appear to be at greater risk for colonization by pulmonary pathogens. Interestingly, the obese and non-obese groups did not require significantly different numbers of surgical interventions, and counter to findings in adult populations, and differences in mortality were not observed. While the causal relationships between obesity and clinical outcomes cannot be inferred from the data, a compelling case can be made for considering a patient’s body habitus as a risk factor for increased morbidity in the form of ventilator days, ICU days, and pulmonary infection. Further research into the connection between body habitus and morbidity in pediatric thermal injury is warranted.

References