Impact of Obesity during Pediatric Acute and Critical Illness

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Abstract

Keywords

- pediatric
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- overweight

Pediatric overweight and obesity rates have reached epidemic proportions and continue to rise globally. Many long-term complications have been described about the impact of obesity; however, little work has been done in the area of acute and critical illness in children. Available evidence suggests that childhood obesity can impact acute and critical illness when compared with normal weight cohorts. This review will discuss the available literature on the impact of pediatric obesity during acute and critical illness.

Introduction

Pediatric obesity has reached epidemic proportions in the United States and other developed and developing countries. Estimates from 2011 to 2012 data calculate that 8.4% of children ages 2 to 5 years, 17.7% of children ages 6 to 11 years, and 20.5% of adolescents 12 to 19 years of age in the United States are obese.¹ These estimates are similar to the U.S. findings from 2003 to 2004 through 2011 to 2012 with exception of a significant decrease in obesity among children 2 to 5 years of age (13.9 to 8.4%; $p = 0.03$).^{1,2} Estimates in the European Union from 2005 to 2006 identified the highest rates of pediatric obesity in the countries of Malta, Spain, Italy, and the United Kingdom. Though, discrepancies in prevalence rates were noted between male and female genders.³ Globally, obesity has increased from 3.7 to 6.1% in developing countries and from 7.9 to 11.7% in developed countries in children 0 to 5 years of age between 1990 and 2010, though variability in these trends exists between countries. Relative rates of obesity have been greater in developing countries when compared with developed countries over the last two decades.⁴ The trend toward increased obesity is expected to rise worldwide.

The rising rate of pediatric obesity is primarily attributed to environmental factors (e.g., dining on fast food, sedentary lifestyle); however, genetic risk has also been demonstrated.⁵ Body mass index (BMI), determined by age, height, weight, and gender, is the most common method to determine

overweight and obesity in children. However, there are challenges to obtaining accurate height and weight in children with acute and critical illness including recumbent position, external lines and tubes, and underlying disease state that can affect baseline weight measure (e.g., dehydration, edema), which can impact the accuracy of BMI calculation. A BMI $\geq 95\%$ for gender and age based upon the growth charts established by the Centers for Disease Control and Prevention categorizes a child as obese.¹ Severe obesity has been described as weight $> 99\%$ percentile for age.⁶ While BMI determination of obesity is not perfect, it is the most efficient and easily performed screening tool currently available. Long-term effects of pediatric obesity include hypercholesterolemia, dyslipidemia, hypertension, insulin resistance, type II diabetes, obstructive sleep apnea (OSA), and impaired quality of life.^{7–13} Many long-term effects of pediatric obesity have been identified; however, much less is known about the impact during acute and critical illness.

Asthma

There are several pulmonary mechanics affected by increased BMI. Pulmonary indices including expiratory reserve volume, forced expiratory volume in 1 sec, diffusing capacity, and maximal voluntary ventilation have been noted to be less than that predicted for gender, height, and body surface area in obese children.¹⁴ While some studies have suggested an association between asthma and obesity, the etiology of the

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association remains unclear.¹⁵ A retrospective chart review evaluating the medical records of 884 children, 682 (77%) lean and 202 (23%) obese, demonstrated no difference in initial asthma scores or asthma management strategies between normal weight and obese children presented to the emergency department. However, obese children demonstrated significantly higher rates of hospitalization when compared with normal weight cohorts.¹⁶ A single center retrospective chart review of 209 children, 164 (78%) lean and 45 (22%) obese, found that obese children with asthma demonstrated higher rates of pediatric intensive care unit (PICU) admission, longer hospital stays, and longer courses of steroids, bronchodilators, and oxygen therapy.¹⁷ Asthma is a common admission diagnosis for PICUs internationally and these findings may help clinicians anticipate the clinical course of disease and devise management strategies.

Traumatic Injury

Pediatric injuries including traffic accidents, falls, submersion injuries, and other mechanisms of injury are a global health problem that can result in a minor ailment, life impairing injury, or death.¹⁸ A retrospective chart review of 1,314 patients, 6 to 20 years of age, who sustained traumatic injury showed that obese children are more likely to sustain an orthopedic injury requiring surgical intervention (55 vs. 40%; $p < 0.001$), develop a deep vein thrombosis (DVT) (0.7 vs. 0.0%; $p = 0.008$), or develop a decubitus ulcer (1 vs. 0.2%; $p = 0.04$) when compared with their normal weight cohorts. Interestingly, they also found that obese children experiencing traumatic injury were less likely to suffer from an intracranial hemorrhage (18 vs. 12%; $p = 0.013$) or intra-abdominal injuries (11 vs. 6%; $p = 0.023$) when compared with normal weight children.¹⁹ A retrospective review of 316 children, 262 (83%) lean and 54 (17%) obese, evaluated the impact of obesity on children sustaining traumatic injury. They reported that obese children admitted to a PICU required longer PICU stays, more days on mechanical ventilation, and experienced higher rates of sepsis, wound infection, and postoperative fistula formation.²⁰ These studies suggest primarily deleterious effects of obesity, and some potential protection offered by obesity in children sustaining traumatic injury.

Burn Injury

A retrospective cohort review of children admitted to one children's hospital burn unit evaluated the effect of obesity on hospital length of stay (LOS) and compared the characteristics of obese and nonobese burn patients. Their study of 528 children admitted to the burn unit included 92 (17.4%) obese children. Total body surface area of the burn, percentage of continuous full thickness burn, Medicaid insurance coverage, and obesity were factors found to negatively impact hospital LOS. Obese children were reported to have a significantly longer LOS (9.3 vs. 7.1 days, $p < 0.05$) when compared with their normal weight cohorts. The authors propose that increased LOS in obese children with burns may be attributed to

complication rates, impaired healing, or greater functional impairment.²¹ A single center retrospective chart review of 592 children with burns involving $\geq 30\%$ of their body surface area were evaluated to identify organ system and clinical challenges encountered in children sustaining burn injury. Children were classified as normal weight ($n = 315$), overweight ($n = 50$), obese ($n = 83$), or morbidly obese ($n = 144$). All patients had similar burn characteristics and demographics. No significant difference was noted in mortality, though a trend toward increased mortality was noted in the first 100 days after the burn injury in overweight, obese, and morbidly obese children. A positive correlation was noted between multisystem organ failure and increasing BMI ($p < 0.00001$). Overweight, obese, and morbidly obese children were found to require increased frequency of surgical interventions compared with normal weight cohorts.²² A retrospective review of children ≤ 18 years of age admitted to a burn intensive care unit without inhalational injury over a 10-year period ($n = 175$; nonobese = 129; obese = 46; $p < 0.05$) demonstrated a significant increase in mechanical ventilation days in obese children (11.65 vs. 3.92; $p < 0.05$). Obese children also had a significant increase in burn intensive care unit LOS (11.59 vs. 5.18).²³

Heart Transplantation

Results in pediatric heart transplant patients are mixed. Kaufman et al²⁴ evaluated the utility of assessing body habitus as a prognostic indicator prior to pediatric heart transplantation. Their retrospective chart review of 180 children, 22 (12%) obese, 66 (37%) wasted, and 92 (51%) lean, reported that obesity at the time of listing for heart transplantation was associated with a three and a half-fold increase in mortality after heart transplantation when compared with normal weight cohorts. Survival rates at 1 and 5 years posttransplant also indicated worse outcomes for obese children. Obese children had 1- and 5-year survival rates of 44 and 31% vs. 71 and 52% in normal weight children ($p = 0.031$). While mortality was impacted by obesity, no statistical difference in serious infections, posttransplant acute rejection episodes, or vasculopathy in the first year after transplantation were noted. Kaufman et al²⁵ performed a retrospective review of 2,333 children ages 2 to 18 years of age using the International Society of Heart Lung Transplant pediatric heart transplant registry. This registry contains pediatric heart transplant data voluntarily submitted by ~80 pediatric heart transplant centers in 13 different countries. In the sample, 546 (23%) children were wasted and 195 (8%) were obese. The remaining children were classified as normal weight. This study demonstrated that obesity at the time of transplantation was not associated with reduced survival in pediatric heart transplant patients, acute rejection, or malignancy. A single center retrospective review of 105 children 2 to 20 years of age, eight (8%) overweight and 22 (21%) underweight, evaluated the impact of being underweight or overweight at the time of heart transplantation. The primary outcome of this study was primary graft survival. The researchers demonstrated that while weight gain after

cardiac transplant was nearly universal, overweight at the time of transplantation did not impact graft survival at 1 year. Conversely, decreased graft function was noted in children who were underweight at time of transplantation.²⁶ While work in the area of how pediatric obesity may affect children receiving a heart transplant is in its infancy, preliminary research demonstrates conflicting evidence on whether obesity at the time of heart transplantation places the child at risk for reduced graft function in the immediate or intermediate postoperative period.

Tonsillectomy and Adenoidectomy

Several studies have identified obesity as a risk factor for OSA. Rates of OSA have been noted to be as high as 13 to 66% in obese children.^{27–30} Some data suggest that adenotonsillar size is correlated with severity of OSA in nonobese children, but not with obese children.³¹ Overweight and obese children ≤ 17 years of age were compared with normal weight cohorts to determine if there were differences in postoperative respiratory outcomes following surgery for sleep-disordered breathing. This single-center study included 98 children, 49 obese and 49 normal weight children. Their findings demonstrate that overweight children have higher rates of postoperative events including PICU admission, unplanned hospital admission, hospital stays longer than 24 hours, and oxygen requirement. The authors acknowledge that some children in the sample underwent procedures beyond intervention for sleep-disordered breathing, increasing operating room time, and potentially confounding findings.³² While postoperative complications may be increased for obese children undergoing tonsillectomy and/or adenoidectomy, Lee et al³³ did not find an increase in anesthesia time in obese children undergoing tonsillectomy and/or adenoidectomy. Shine et al³⁴ performed a retrospective review of 18 morbidly obese children ages 2 to 18 years of age with OSA confirmed with either polysomnogram or pulse oximetry study. The primary aim of the study was to determine if surgical intervention with adenotonsillectomy eliminated the need for continuous positive airway pressure support postoperatively in these children. Postoperative respiratory disturbance index decreased from 20.7 to 7.3 ($p = 0.001$) and oxygen saturation nadir changed from 77.5 to 88.5% ($p = 0.007$). While each child demonstrated improvement in their respiratory parameters, approximately half ($n = 10$; 53%) of the children demonstrated significant residual OSA requiring ongoing continuous positive airway pressure support. The small sample size of this study may preclude generalization of findings. These studies suggest mixed results in postoperative complication rates; though they demonstrate overall improvements in respiratory parameters after adenotonsillectomy in obese children.

Perioperative Complications

A large retrospective database review by Nafiu et al³⁵ reviewed more than 6,000 operative cases, comparing normal weight children with overweight and obese counterparts.

Their findings included significantly higher American Society of Anesthesiologists physical status classification scores ($p = 0.0006$), higher prevalence of medical comorbidities such as hypertension and asthma, and higher rates of difficult mask ventilation ($p = 0.001$) and laryngoscopy ($p = 0.005$) in overweight and obese children. Postoperatively, overweight and obese children were more likely to have prolonged postanesthesia care unit stays, largely due to episodes of upper airway obstruction, and increased use of antiemetic agents. Tait et al³⁶ reported similar results in their study of 2,025 (1,380 normal weight, 351 overweight, and 294 obese) children 2 to 18 years of age. They reported a higher incidence of difficult mask ventilation, airway obstruction, major desaturation ($> 10\%$ change in from baseline), and overall critical respiratory events in obese children. Risk factors for adverse events noted after logistic regression included airway procedures, obesity, age < 10 years, and history of OSA. Nafiu and Onyewuche³⁷ performed a prospective observational review of 1,102 children undergoing elective noncardiac surgery. Abdominal obesity was present in 23.1% of the children undergoing surgery. Abdominal obesity independently predicted relative odds of adverse respiratory events ($p < 0.001$) and was associated with longer postanesthesia care unit stays.

Deep Vein Thrombosis

Although DVTs are not common in pediatric patients, surveillance vigilance is warranted due to associated morbidity and mortality if unrecognized. A pediatric inpatient database review study evaluated risk factors for the development of a lower extremity DVT. The study included children 1 to 17 years of age hospitalized for at least 4 days. Older children (e.g., 15–17 years of age) with comorbid conditions were more likely to develop a DVT. Obesity was one of the comorbid conditions identified as a risk factor in development of a DVT (prevalence ratio 2.1, 95% confidence interval 1.5–2.8).³⁸ Other comorbid conditions associated with development of DVT included inflammatory bowel disease, malignancy, and thoracoabdominal or orthopedic surgery. Unlike the study by Rana et al,¹⁹ trauma was not associated with an increased risk for DVT in their study sample.

Cardiac Arrest

A retrospective review of in-hospital cardiac arrest events in children < 18 years of age reported to the American Heart Association National Registry of Cardiopulmonary Resuscitation was performed between January 2000 and July 2004. A total of 1,268 children were included in the analysis and 213 (17%) were categorized as obese (≥ 95 th weight-for-length percentile if < 2 years of age or ≥ 95 th BMI-for-age percentile if ≥ 2 years of age), adjusted for gender. Self-reported cardiopulmonary resuscitation quality by the performing clinicians was poorer in obese children. Obese children experiencing in-hospital cardiac arrest were less likely to survive the event (adjusted odds ratio 0.58 [95% confidence interval 0.35–0.76]) and less likely to survive to hospital

discharge (adjusted odds ratio 0.62 [95% confidence interval 0.38–0.93]).³⁹

Pediatric Intensive Care Unit Morbidity and Mortality

Two studies were identified that investigated the impact of pediatric obesity during critical illness. Both studies were single center retrospective chart/database reviews, one in the United States and one in Australia. Goh et al⁴⁰ compared the outcomes of 1,030 children between the ages of 2 and 18 years admitted to the PICU requiring mechanical ventilation at one Midwest children's hospital. The sample included 753 normal weight, 137 overweight, 76 obese, and 64 severely obese children. This retrospective database review used the Virtual PICU Performance System database to compare mechanical ventilator days, PICU days, and mortality in normal weight, overweight, obese, and severely obese patients. A weight for age z-score was used to determine patient weight category. A univariate analysis was used to compare groups, multivariate logistic regression to compare mortality, and linear regression to compare ventilator days and PICU LOS. Their findings showed no significant difference in ventilator days, PICU days, or mortality when adjusting for admission type (scheduled vs. unscheduled), trauma status, operative status, and admission functional status, and severity of illness scoring. Obese and severely obese children in this study comprised ~12% of the sample size, which underrepresents the U.S. national average. Body weight classification was determined using a weight-for-age z-score rather than BMI, due to absent length/height documentation in many study patients.⁴⁰

Numa et al⁴¹ evaluated the effect of extreme weight centiles in 6,335 children admitted to an Australian PICU over an 8.5-year period. All patients admitted to the PICU from January 2002 to June 2010 were eligible for study inclusion. Weight-for-age z-scores were calculated from Center for Disease Control and Prevention charts and then converted to a centile. Weight centile and mortality were evaluated with Copas p by x plots and then confirmed with Mann-Whitney U-test. Univariate and multivariate logistic regression was used to evaluate the relationship between Pediatric Index of Mortality Version 2 severity of illness score variables with weight centile and mortality. Pediatric Index of Mortality Version 2 coefficients were used to calculate standardized mortality rates. Patients with extremes in weight centile were reported to have increased mortality in the PICU when compared with normal weight children. Data from underweight and overweight children were analyzed in the same group, which may have skewed results. Combining children at both spectrums of the weights centiles in analysis did not allow the ability to discern differences in outcomes between underweight and overweight children, resulting in the inability to specifically determine the impact of obesity on mortality.

Limitations

There are several limitations in the studies discussed. Most studies were performed as retrospective chart reviews. Missing weight in height data points in the medical record and

potential for inaccurate height and weight recorded may impact accuracy of data. Accuracy of documented height and weight is especially of concern in children who are admitted during acute illness when patient stabilization and safety are the priority. Fluid resuscitation and third spacing of fluid or admission dehydration may impact the weight of the child lead to inappropriate weight classification. Additionally, nursing and other staff responsible for obtaining height and weight values upon admission may be unaware that the data they are obtaining may be used for research purposes, impacting the accuracy of the measurements for calculating body mass measurements. Inaccurate measurements affect classification of weight classification category and ultimately study results.

Discussion

Largely, obesity has negative impacts on children that are acute and critically ill. Anatomic alterations as a result of adiposity can affect pharmacologic metabolism, obscure physical landmarks increasing the difficulty of procedural therapy (e.g., central venous catheter placement), and lead to redundant airway tissue, which may elevate the difficulty of airway visualization and intubation. Underlying chronic inflammation due to obesity may affect the complex pathophysiologic interaction of single or multiorgan system disease or disease trajectory, negatively impacting of the course of disease in acute and critically ill children.⁴² The level of chronic inflammation in childhood is unknown and may be hypothesized to occur at a lower level since the duration of adiposity exposure is for a shorter duration in children.

Determining appropriate nutritional and caloric goals for obese acute and critically ill children is necessary in preventing untoward complications, though this can be challenging clinically.⁴³ Caloric needs in acute and critically ill children are different from healthy children. Risks of overfeeding acute and critically ill children include hyperglycemia, prolonged mechanical ventilation hospital stays, and in extreme cases, death.^{44,45} Several equations are available to estimate caloric requirements; however, these equations frequently underestimate or overestimate patient energy requirements. Actual resting energy requirements can only be assessed using indirect calorimetry and this method has been recommended by American Society for Parenteral & Enteral Nutrition for several patient populations including obese children to avoid unintended consequences of inappropriate caloric delivery.⁴⁶

Pediatric obesity is associated with increased financial burdens. A retrospective database review of obese children admitted for one of four common pediatric admission diagnoses (asthma, pneumonia, affective disorder, and appendicitis) and a secondary follow-up study of the same population showed a significant increase in hospital charges and increased LOS in obese children.^{47,48} A retrospective cohort review of children ages 2 years to < 18 years of age evaluated the records of 32,996 children presenting to a single center Emergency Department. Acute care costs were not different between normal weight and overweight children; however, children requiring hospitalization for asthma, fractures, or

dislocations had statistically significant higher median hospital charges than their normal weight cohorts.⁴⁹

Summary

In conclusion, while not all of the studies discussed in this article have included patients from the PICU population, many themes can be extrapolated to similar patients requiring procedural or surgical intervention or those admitted to the hospital of PICU with asthma, OSA, burn and traumatic injury, and heart transplantation. Familiarity with this evidence can lead to thoughtful decision-making when managing obese children. This may allow increased ability to anticipate illness trajectory or prognosis, as in cases with cardiopulmonary arrest. The review of these studies substantiates the need for ongoing research in pediatric obesity prevention and therapy to reduce the disparities between negative clinical outcomes and associated costs with obesity in acute and critically ill children. Future research is needed to more clearly delineate the impact of pediatric obesity on acute and critical illness and to pursue strategies to minimize the gap between outcomes of obese children and their normal weight counterparts.

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