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Obesity As A Risk Factor For Hospital Acquired Infections In Pediatric Trauma Patients: A Pilot Study

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Obesity as a Risk Factor for Hospital Acquired Infections in Pediatric Trauma Patients
A Pilot Study

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INTRODUCTION

Obesity is the excess of adipose tissue, or fat, on the body. Formulated by the World Health Organization, the Body Mass Index (BMI) is the widely accepted method for measuring excess body fat in individuals. Basically, the BMI determines if the weight of individuals is within healthy limits for their height (Willett, 1999). The following table lists categories of BMI with the range of possible BMI values:

BMI Category	kg/m^2
Underweight	< 18.5
Normal	18.5 to 25
Overweight	25 to 30
Obese	< 30

But, of course, like many measures, the BMI has its limitations. For instance, individuals with high muscle mass can be classified as overweight or, in the case of body builders, obese. However, these flaws in BMI accuracy do not take away from its usefulness in the clinic or in research. As we will see, BMI has been seen to be an indicator for several diseases and clinical complications, especially Hospital Acquired Infections (HAIs).

In epidemiology, the BMI measurement has been a useful tool in tracking the changes in obesity prevalence in the United States. In 1950, 9.7% of the population was obese, or had a BMI over 30 (Flegal, 2002). In 2000, that number increased to 30.5%. This dramatic increase in obesity prevalence is linked with certain aspects of modern Western culture. Obesity is chiefly the result of both the over consumption of energy-dense foods that are high in fat and sugar and technological innovation, which has encouraged a greater number of people to live sedentary lifestyles.

This rise in obesity prevalence has been labeled an epidemic and should be of concern to those in public health. Obesity has serious adverse effects on human health, particularly with the role it plays as a precursor to many chronic diseases, such as cancer, diabetes and heart disease (Haslam, 2005). These conditions have been consistently ranked in the top 10 causes of mortality in the United States in the past decade (Kochanek, 2004), claiming approximately 300,000 lives a year (Allison, 1999).

More alarming is that the obesity epidemic has extended to children. The prevalence of obesity among Americans in the 6 to 19 year old category has tripled since the 1960's. Today, 50% of individuals in this age group are either overweight or obese (Kimm, 2002). This rise in childhood obesity has been coupled with the incidence of chronic diseases that are traditionally associated with the elderly. Conditions, such as type II diabetes, are being seen more and more in children as young as 6 years old (Young, 2000). In 1980, the prevalence of type II diabetes in American children between ages 6 and 11was 6.5% in 1980. In 2008, that figure tripled to 19.6% (Daniels, 2002).

Furthermore, these obesity related conditions may have the added burden of weakening the body's immune system and lead to a greater likelihood for infection. Infection occurring as a result of chronic conditions, such as diabetes, is an acknowledged association; but, evidence in the literature now shows that obesity itself may be an independent risk factor that renders the body vulnerable to infectious agents.

This ought to be of particular interest to the fields of hospital epidemiology and infectious diseases. Patients in a health care setting are already vulnerable to infection from hospital exposures and interventions; but the added risk for infection brought from obesity may indicate a need for stronger infection control practices and a greater understanding of how to treat this prevalent patient profile.

Obesity and Infection

Pathophysiology

On a molecular level, there is growing evidence suggesting that obesity itself may increase a patient's risk for infection. In studies that have used both human and animal models, it has been shown that increased percentage of body fat weakens the body's immune system (Falagas, 2009). This is likely due to the continuous, mild inflammation present in the extraneous subcutaneous, adipose tissue. This inflammation initiates pathways that decrease the concentration of leptin, a hormone involved in energy metabolism and immune cell activation. Thus, a decrease in leptin, as caused by obesity, was observed to cause subjects to have impaired immunological cells and, thus, a more vulnerable defense against infectious agents (Farooqi, 2002) (Bastard, 2008).

Increased Risk for Respiratory Infection

Another condition inherent to obese individuals is their likelihood for a compromised respiratory function. An obese individual's extra weight on the torso may compress the chest cavity and alter lung mechanics, respiratory muscle dysfunction and augment airway resistance. The affects may be apparent with increased work of breathing and less effective gas exchange at the alveoli.

As a result, obesity has been associated with Obstructed Sleep Apnea, a condition where the airway is greatly diminished or obstructed when the person is laying down. Consequently, this condition poses a risk for gastrointestinal (GI) aspiration. Aspiration refers to the entry of contents from the GI tract into the larynx and lower respiratory tract. If aspiration occurs, microorganisms and debris may enter and overwhelm the respiratory tract's defenses, creating a great risk for an infection, particularly aspiration pneumonia (Koenig, 2001).

In a 1998 study comparing obese and non-obese patients in the post-operative period, the obese patients were seen to have a greater incidence of aspiration pneumonia. According to researchers, a number of comorbidities present in the post-operative obese patient rendered them at risk for this condition, particularly because of a higher incidence of gastro-esophageal reflux (Vaughan, 1975). These findings strongly suggested that clinicians ought to avoid placing their obese patients in horizontal positions during post-operative recovery and rather have them sit upright or semi-upright (Marick, 1998). Already, from such evidence, clinicians have acknowledged that the obese patient is indeed different and needs some clinical accommodations.

Obesity Comorbidities

As previously mentioned, obesity is linked to conditions such as diabetes, heart disease and cancer. These conditions may greatly weaken the immune system and predispose patients to infection. Diabetes mellitus comes with symptoms such as hyperglycemia, neuropathy, and impaired tissue perfusion, all of which may severely impair the immune system (Pozzili, 1994). Similarly, cardiac disease increases the likelihood of sepsis (Leibovici, 1995) and pneumonia (Fine, 1997). In addition, certain cancers are associated with obesity and may leave the body immune-compromised, especially when those afflicted are subsequently treated with radiation or chemotherapy.

Though initially caused by obesity, these conditions increase the likelihood of complications, like HAIs, during medical care. As we will see in the studies that follow, when researchers are analyzing obesity's effect on infection risk, they control for these comorbidities, either through exclusion criteria in recruitment or with statistical analysis modifications. The intent of the researchers is to isolate obesity to detect if it independently contributes to a patient's risk for infection.

Greater Infection Severity

An example of such a study comes from Great Britain, where researchers sought to describe 1520 patients, aged 5 to 54 years old, admitted for flu during the H1N1 outbreak between May 2009 and January 2010 at 75 UK hospitals. The researchers isolated those who had a *severe outcome* as a result of flu*,* which was defined as admission into intermediate or intensive care or death. With comorbidities controlled, researchers concluded that obese individuals with the flu were twice as likely to have a severe outcome as their non-obese counterparts (adjusted OR 2.22; 95% CI 1.18 - 4.18). Researchers attribute the obese patients' particular vulnerability to a flu infection because of obesity's compromising effect on respiration and the continuous pro-inflammatory state previously described (Myles, 2012). This data strongly suggests that obesity may impair the immune system's ability to fight an infection; however, the researchers agree that more research is needed to further clarify this association.

Hospital Acquired Infections

Patient Care/Vascular Access

From the perspective of clinicians, the obese patient poses several difficulties. A patient's heavy weight may hinder transfer to reach appropriate care and perform rehabilitating treatments, such as physical therapy. As a result, obesity may act as a physical obstacle to a patient's recovery and may extend a patient's hospitalization. Prolonged length of stay at the hospital is a risk factor for infection. In one study, obese patients were in the hospital for an average of 10 more days (95% CI = 6.8–13.4, $p<0.001$) and in the ICU for nearly 8 more days (95% CI = 5.1–10.4, $p<0.001$) than their non-obese counterparts (Bochicchio, 2006). The hospital is a congregation of ill patients and a variety of pathogens; the longer the patient is in this environment, the greater the chance for an exposure to an infectious agent.

In addition, gaining vascular access in the obese patient may be more challenging for clinicians. The adipose tissue leaves a greater distance from the surface of the skin and the vein, making veins less visible. The greater number of attempts for vascular access creates more breaks in the skin and more opportunities for infections to develop (El-Solh, 2001).

Surgical Site Infections

Patients with more adipose tissue are at a greater risk for a Surgical Site Infection (SSI). Adipose tissue receives a relatively lower blood supply than other types of tissue. The decreased blood flow hinders immune cells access to the site of incision, increasing healing time and decreasing the body's ability to control microorganism activity (Falagas, 2009)(Canturk, 2003)(Fleishmann, 2005).

A retrospective case-control by Olsen in 2008 studied patients who had had an orthopedic spinal operation at a university-affiliated tertiary-care hospital from 1998 to 2002. Forty-six patients with a superficial, deep, or organ-space surgical site infection were identified and compared with 227 uninfected control patients. Through multivariate analysis, researchers found that diabetes (odds ratio = 3.5, 95% confidence interval = 1.2, 10.0), suboptimal timing of prophylactic antibiotic therapy (odds ratio = 3.4, 95% confidence interval = 1.5, 7.9), a preoperative serum glucose level of >125 mg/dL (>6.9 mmol/L) and two or more surgical residents participating in the operative procedure (odds ratio = 2.2, 95% confidence interval = 1.0, 4.7) contributed to SSI risk. More importantly, obesity was found to have a significant (95% CI = 1.1, 4.7) odds ratio of 2.2, meaning that obese patients were twice as likely to have an SSI than non-obese patients. As we see from the results here, many factors are involved with infection risk. Obesity is but one of these factors but plays a significant role none the less. A number of studies have echoed this association proposed by Olsen between obesity and risk for SSIs (Olsen, 2002) (Vilar-Compte, 2000) (Crabtree, 2004).

Device Use and Length of Stay

Often times when patients are critically ill, medical devices are utilized, such as endotracheal tubes for mechanical ventilation, central venous lines for vascular access, and Foley catheters for urinary drainage. However, these devices create a breach in the innate barrier to organisms and put the patient at a greater risk of exposure to potentially harmful microorganisms.

A 2006 study by Bochicchio, found that obese patients (BMI >30) were more likely to have these devices for longer periods of time. Obese patients also experienced an average of 8 more days on mechanical ventilation (8.2 (95% CI 5.5–10.96) $p<0.001$), 11 more days on a Foley catheter (10.9 (95% CI 8.14–13.5) $p<0.001$) and 11 more days with a central venous line (11.1 (95% CI 9.2–13.9) $p<0.001$) when compared to non-obese, control patients. Other studies have concurred that patient obesity is clearly associated with longer device use (Yaegashi, 2005) (Richards, 1999) (Brown, 2006).

A possible reason for prolonged mechanical ventilation in the obese patient may partially be attributed to the reduced lung capacity and increased work of breathing inherent with obesity. In addition, the difficulty in accessing and maintaining peripheral intravenous catheters in obese patients, may, in part, explain why clinicians may opt for a central venous line. Since obese patients are more likely to have greater length of stays, a central venous line may be more practical than peripheral venous catheters, which usually need to be changed every 3-4 days.

Device Use and Length of Stay in Pediatrics

Pediatric patients have a similar risk for HAIs under similar conditions, namely prolonged device use and length of stay. In the largest investigation of its kind, Richards et al. in 1999 conducted a retrospective study that observed 110,709 pediatric patients in 61 pediatric intensive care units (PICU) and neonatal intensive care units (NICU) in the US. Using CDC/NHSN surveillance definitions for infections (which will be later discussed), researchers found 28% had bloodstream infections, 21% had pneumonia and 15% had urinary tract infections (UTIs). The average rate of infection was 6.1 infections per 100 patients and was strongly correlated with ICU length of stay ($r = 0.45$, $p= .0002$). In addition, each type of infection was strongly associated with corresponding device use. For patients with bloodstream infections, 91% had a central venous catheter. In cases of hospital acquired pneumonia, 95% were in patients on mechanical ventilation. And finally, 77% of patients with UTIs had Foley catheters ($r = 0.40$, $p = .001$). Just as in adults, medical device usage renders the pediatric patient more vulnerable to the outside environment, and, as a result, at an increased risk for infection.

Hospital Acquired Infections in the Obese

The next step in research looked specifically at whether the obese patient was at a higher risk for HAIs. A 2004 case-control by Bercault matched 170 obese patients (BMI >30) with 170 normal

weight patients that were all mechanically ventilated. The obese group experienced a greater rate of septic shock (8% vs. 3%) and a greater rate of infection (24% vs. 15%). Infections observed included ventilator-associated pneumonia, bloodstream infection, and deep surgical site infection; again, all as defined by the CDC/NHSN surveillance criteria. In addition, Bercault found that obese patients were 2.1 times more likely to die in the ICU than non-obese patients, with possible confounders such as cancer and diabetes being controlled. Researchers claim that the obese patient's risk for complications, such as infection, may contribute to greater mortality and recommend that clinicians treat infections in the obese more aggressively as to prevent adverse events. From this study, we see that obesity may complicate medical treatment by prolonging device use and increasing the likelihood of infection.

Trauma and HAIs

The study presented in this paper is composed solely of pediatric trauma patients. A severe traumatic injury creates a hyper-inflammatory environment in the body that severely compromises the immune system (Tschoeke, 2005). This reaction coupled with the altered physiology and immune system of the obese patient may put the obese trauma patient at a severe risk of infection.

Several studies have looked at the effects of obesity on a trauma patient's risk for clinical complications and overall survival. In a 2010 study by Serrano, researchers conducted a case control that looked at 1,024 trauma patients in a one year period. Of these patients, 30.6% were obese. The CDC/NHSN definitions for HAIs were used and found to be associated with obesity, prolonged hospital length of stay, presence of multiple comorbidities and prolonged ICU length of stay. Overweight (BMI 25 to 29) patients were 2.65 (CI 0.72 to 5.72) times more likely than normal weight patients to have an infection. Those considered obese (BMI 30 to 39) were 4.69 times more likely than patients of normal weight to have an infection (CI 2.18 to 10.08). And finally, those who were morbidly obese (BMI > 40) were 5.91 time more likely to have an infection (CI 2.18 to 16.01). Researchers concluded that obesity was determined to be an independent risk factor for infection, when controlling for comorbidities such as diabetes.

A recent study by Edmonds et al. in the Journal of Trauma takes it a step further and treats BMI as a continuous variable, rather than a categorical one. This allows Edmonds et al. to determine

that for every point increase in BMI, the risk of acquiring a hospital acquired infection, as defined by the CDC, increases by 7%. The author concludes that obesity exacerbates the post-traumatic patient condition and is a risk factor for infection during hospital stay.

Pediatric Trauma Study (Brown, 2006)

In a study by Brown in 2006, the question of obesity's effect on a trauma patient's mortality and risk for complications was evaluated in children. Researchers recruited 316 pediatric and adolescent trauma patients (6 – 19 years old) and calculated BMI percentiles (later explained in my Methods section). Regarding differences in mortality between obese (BMI > 95 percentile) and non-obese patients (BMI percentile < 95), Brown found no significant difference in mortality (15% vs. 9% respectively $p = 0.39$). On the other hand, obese children were observed to have more significantly more clinical complications (41% vs 22%, $p = 0.04$). Clinical complications were defined as use of medical devices, prolonged length of hospitalization and some infections.

Brown found that obese children had more sepsis (15% vs 4%, $P = .007$), wound infection (26% vs. 8%, $p = .03$), and needed one more day of mechanical ventilation (5 ± 7 vs. 4 ± 5 days, $p = 0.22$) when compared to non-obese patients. Looking at hospitalization time, obese patients had longer stays in the ICU (8 ± 9 vs. 6 ± 6 days, $p = .05$) and, on average, stayed in the hospital 4 days longer (18 ± 19 vs. 14 ± 12 days, $p = .08$) than non-obese patients. With these results, Brown argues for further research on the effects of obesity and medical care; arguing for a better understanding on what treatments may be more appropriate for this particular demographic of patients.

PURPOSE AND STUDY QUESTION

I have outlined the evidence in the literature that strongly suggests that obese trauma patients are a particularly vulnerable group to infection. The purpose of this was study to act as a continuation of the Brown study in 2006 and assess the trauma patients' risk for all infections that arose during hospitalization, not just sepsis and wound infection. In addition, factors that heighten the risk of infection, such as length of stay and prolonged device use, were also evaluated.

METHODS

Study Design

A retrospective chart review of pediatric patients entered into the Trauma Registry at Dell Children's Medical Center of Central Texas (Dell Children's or DCMC).

Setting

Dell Children's is a 176 bed Level I Trauma Center with a catchment area that encompasses 46 counties in Central Texas. In a given year, the hospital admits approximately 8,000 patients and receives around 47,000 patients into its Emergency Room.

Inclusion criteria:

Pediatric (ages 0 – <18 years old upon admission) trauma patients with a hospitalization of 48 hours or more from July 1st 2010 until March 31st 2011.

Exclusion criteria:

Since this is a pediatric study, all patients 18 years or older were excluded. Patients with immune-compromising conditions were excluded, though no one in this study was excluded for such reasons:

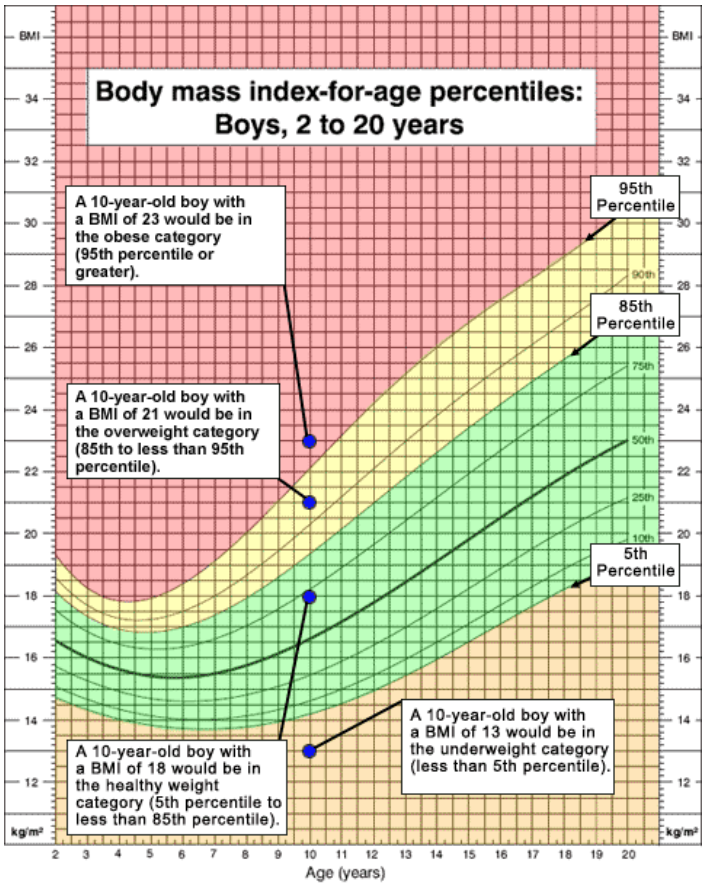
1) Congential Immunodeficiencies
2) Human Immunocompromising Virus (HIV)/AutoImmune Deficiency Syndrome (AIDS)
3) Hematological Malignancies
4) Immunosuppressed patients

BMI percentile

BMI was calculated using the following The Centers for Disease Control and Prevention definition (CDC, 2011):

$$\text{BMI} = (\text{mass in kg})/(\text{height in m})^2$$

Once BMI was calculated we then account for differences in body fat between boys and girls of different ages. A child's BMI was reported as the percentile that BMI falls in the national average of BMIs for that age and sex. For instance, the following graph shows BMI percentiles for boys ages 2 to 20 years old.



The percentile in which a subject's BMI is placed determines their weight category. The CDC has created 4 categories that were used in this study:

Underweight	< 5th percentile
Healthy weight	5th to < 85th percentile
Overweight	85th to < 95th percentile
Obese	≤ 95th percentile

Data Sources

The data was extracted from the Trauma Registry and/or the medical record.

Trauma Registry Data

The following are variables we received from the registry followed by an explanation for their use in the study:

1. Name/MRN – to identify the patient and retrieve other data points from the medical record

2. Date of birth or age – to make certain that only pediatric patients are included and for BMI percentile calculation
3. Race/ethnicity– to describe our cohort and see if it is comparable to other pediatric trauma cohorts
4. Sex – for BMI percentile calculation
5. Injury Severity Score (ISS) – "an anatomical scoring system that provides an overall score for patients with multiple injuries. Each injury is assigned a severity score (0 the lowest, 6 the highest) and is allocated to one of six body regions (Head, Face, Chest, Abdomen, Extremities (including Pelvis), External). Only the highest severity score in each body region is used. The 3 most severely injured body regions have their score squared and added together to produce the ISS score" (Baker, 1974).
   ISS scores could be potential confounders in risk of infection, where an increased ISS score could make a patient more vulnerable to potential pathogens.
6. Admission date, discharge date – to calculate length of stay
7. Weight and height – to calculate BMI percentiles
8. Mechanical Ventilation Days – a known risk factor for developing infections

Chart Review

Days with a Central Venous Line (CVL)

CVL insertion was performed by physicians with date and time of insertion noted in the Physician Progress notes. Date and time of a discontinued CVL line was also noted in these progress notes either explicitly or through the insertion of a Peripherally Inserted Central Catheter (PICC). At DCMC, a CVL is usually removed when a PICC is inserted. If CVL removal was not noted then time of PICC insertion was used as the end time for that CVL.

Antibiotic Use

The Pharmacy Department cross-referenced our cohort with a list of antibiotics not commonly used prophylactically. All antibiotics were cross-referenced except for cefazolin (Ancef), the commonly used prophylactic antibiotic used in surgery at DCMC.

Laboratory Results

Each patient's medical records were reviewed for positive cultures occurring more than 48 hours after admission. The results of any virology tests were also examined. A Complete Blood Count

(CBC) with a high white blood cell (WBC) count more than 48 hours after admission was also noted. Abnormal WBC counts were highlighted in red in the electronic record for clinician awareness. For the purposes of the study, the threshold for a high WBC count was at or above 10,500 leukocytes per microliter of blood for all age groups.

Nurse's Notes/Respiratory Therapist Notes

These clinician notes were reviewed for documented fevers and qualitative data that fulfill certain NHSN criteria for infections. Body temperatures at or above 100.5 °F were noted. These documents were originally in paper format and allowed nurses and respiratory therapists to chart observations. In patients with positive cultures, these sections were analyzed for qualitative data indicative of infection such as purulent discharge, inflammation and changing breath sounds depending on where the positive culture was taken.

Data Entry and Analysis

The data from the Trauma Registry was received in a Microsoft Excel spreadsheet with 1279 observations. The variables from the chart review were added to the same spread sheet. The BMI percentile calculations in Table 2 of the Results section required the use of a program provided by the CDC website. This determined a child's percentile when matched to national BMI data for specific sex and age combinations.

Once data entry was complete, the Excel file was exported to SAS for statistical analysis. After cleaning the data for missing values, the univariate analysis function was utilized to describe our sample and create Table 1. In the Table, all of the data was converted to ordinal variables. For instance, continuous variables such as BMI percentile were categorized into obese, overweight, normal or underweight groups. In Table 3, we utilized the frequency procedure in SAS to stratify the data and utilize the Chi-Squared test to analyze if our variables across BMI categories were statistically different from one another.

RESULTS

Table 1

The Trauma Registry had 1279 pediatric patients for DCMC entered between July 1st 2010 until March 31st 2011. This sample included patients that were not admitted to the hospital or had a hospitalization period less than 48 hours. As will be discussed later on, the surveillance definition for a HAI requires that the patient be in the hospital for more than 48 hours to increase the likelihood that the infection was actually acquired in the health care setting. Thus, from these 1279 patients, I only included patients that were in the hospital for 48 hours or more, leaving me with 315 patients.

Table 1 describes our initial study group of these 315 pediatric trauma patients. The cohort had an average age of 6.7 years (± 4.6). Stratified by age groups, 11.4% of the cohort consisted of infants (0-1 years old), 19.1% were Toddlers (1-3 years old), 15.2% were Middle Childhood aged (6-11 years old) and Teenagers represented 33.3% of our study group. The cohort consisted of 62.9% males and 37.1% females. With regards to race, 52.1% were white, 33.7% were Hispanic, 8.9% were Black, 3.8% were Asian and 1.6% were classified by the registry as "Other".

With regards to events that occurred during hospitalization, 51.8% had a length of stay of 2 days, 15.2% had a length of stay of 3 days, 8.6% had a length of stay of 4 days and 24.4% had a length of stay of 5 days or more. Admission to the Pediatric Intensive Care Unit (PICU) was experienced by 7.6%, 9.9% required mechanical ventilation, and 4.1% required vascular access with a central venous line (or central venous catheter). Within the study time period, 2 deaths in occurred in this cohort as a result of their traumatic injuries.

There were three methods for tracking infections in this group. I looked at non-prophylactic antibiotic-use and used 2 different infection surveillance methods: ICD-9 codes for infections and patients classified as having HAIs by the Infection Prevention Department at DCMC. As we see in Table 1, nearly 29% of the cohort used non-prophylactic antibiotics. Nine patients overall had ICD-9 codes for infections, as noted by a physician. But, on the other hand, the Infection Prevention Department accounted for only 3 HAIs in this cohort.

Table 1. Description of Study Group (n=315)

Characteristic	**N (%)***
Sex	
Male	198 (62.9)
Female	117 (37.1)
Race/ethnicity	
Non-Hispanic white	164 (52.1)
Non-Hispanic black	28 (8.9)
Hispanic	106 (33.7)
Asian	12 (3.8)
Other	5 (1.6)
Age (years), mean ± SD	6.7 ± 4.6
Age (years)	
Infant (0-1)	36 (11.4)
Toddler (1-3)	60 (19.1)
Middle Childhood (6-11)	48 (15.2)
Teenager (12 – 18)	105 (33.3)
Hospital Length of Stay	
2	163 (51.8)
3	48 (15.2)
4	27 (8.6)
5≤	77 (24.4)
ICU Admission	
Yes	24 (7.6)
No	258 (81.9)
Mechanical Ventilation	
Yes	31 (9.9)
No	284 (90.1)
Central Venous Catheter	
Yes	13 (4.1)
No	302 (95.9)
HAI per CDC definition.	
Yes	3 (1.0)
No	312 (99.0)
ICD-9 Codes for Infection	
Yes	9 (2.9)
No	306 (97.1)
Non-prophylactic Antibiotic use	
Yes	91 (28.9)
No	224 (71.1)
Death during hospitalization	2 (0.63)

* Numbers may not add up to 315 and percentages may not add up to 100% due to missing values.

HAI cases in Table 1

The 3 HAI cases in my cohort were determined to be hospital acquired by Infection Prevention Specialists at DCMC when the cases fulfilled guidelines for HAI identification as outlined by the CDC/NHSN. With regards to BMI percentiles, 2 of these patients were normal weight and 1 had an unknown BMI. All of these cases experienced severe trauma (ISS scores of either 36 or 38). All were admitted to the ICU and placed on mechanical ventilation and 2 had a CVL inserted. All were prescribed non-prophylactic antibiotics.

Table 2

The cohort of 315 pediatric trauma patients were then placed in their BMI categories after their BMI percentiles were calculated. Of the 315 patients included in Table 1, 194 patients had valid height and weight measures available; 10% of the 194 patients were underweight, 48% were normal weight, 42% of our cohort were either overweight or obese. Height and weight variables were not available for 121 of our study group.

BMI Percentiles for Study Group

	Boys	**Girls**	**Total**
Number of children assessed:	127	67	**194**
Underweight (< 5th %ile)	11%	7%	**10%**
Normal BMI (5th - 85th %ile)	43%	57%	**48%**
Overweight or obese (≥ 85th %ile)*	46%	36%	**42%**
Obese (≥ 95th %ile)	*28%*	*22%*	***26%***

***Terminology based on: Barlow SE and the Expert Committee. Expert committee recommendations regarding the prevention, assessment, and treatment of child and adolescent overweight and obesity: summary report. Pediatrics. 2007;120 (suppl 4):s164-92.**

Table 3

In Table 3, the study group is stratified by BMI so that the distribution of each variable of interest can be easily observed among these categories. Since the focus of the study surrounds the effect of excess of adipose tissue on the risk for infection, Table 3 includes normal weight patients (n = 93), overweight patients (n=31) and obese patients (n=51). This further reduced our study size to a final study group of 175 pediatric patients.

Regarding the makeup of each category, the average age of obese patients was 9.1 years (± 3.3), overweight were also 9.1 years (± 4.6) and normal weight patients were slightly younger with an average age of 7.5 years (± 3.8). The distributions for gender between these groups were similar; there seemed to be a greater likelihood for the pediatric trauma patients to be male. For instance, 70.6% of obese patients, 71.0% of overweight patients and 59.1% of normal patients were male in the study group.

The variables of interest for this study were risk factors for infections and infections themselves. Prolonged length of stay was arbitrarily classified as being 5 days or longer. Over 21% of obese patients, 16.1% of overweight patients and 20.4% normal weight patients experienced long hospitalizations. Out of the 3 total Central Venous Line insertions in this study group, 2 occurred in obese patients and the other was experienced by normal weight patients. And finally, 5.9% (n=3) of those in the obese category, 12.9% (n=4) of those that were normal weight, and 4.3% (n=4) of normal weight patients were mechanically ventilated.

I applied the chi-square statistical test between these 3 BMI categories for each of the variables in Table 3 to assess if a difference between them existed; however, no statistical significance was present. Though the sample size was not sufficiently large to gain statistically significant findings, some trends and discrepancies between infection surveillance methods can be discussed.

Table 3. Sample stratified by BMI Percentile*
(n = 175)

Characteristic	Obese (n = 51)	Overweight (n = 31)	Normal (n = 93)
Age (years), mean ± SD	9.1 ± 3.3	9.1 ± 4.6	7.5 ± 3.8
Sex, n (%)			
Male	36 (70.6)	22 (71.0)	55 (59.1)
Female	15 (29.4)	9 (29.0)	38 (40.9)
Race/Ethnicity, n (%)			
White Non-Hispanic	25 (49.0)	16 (53.3)	52 (56.5)
Hispanic	20 (39.2)	11 (36.7)	30 (36.6)
Black Non-Hispanic	4 (7.8)	2 (6.7)	8 (8.7)
Other	2 (3.9)	1 (3.3)	2 (2.2)
Financial Status, n (%)			
Medicaid	20 (39.2)	15 (49.1)	44 (47.8)
Commercial Insurance	23 (45.1)	13 (28.9)	34 (37.0)
Private Pay	4 (7.8)	3 (15.3)	7 (7.6)
Chip	2 (3.9)	0 (0)	2 (2.2)
Other	2 (3.9)	0 (0)	5 (5.4)
LOS (days), n (%)			
2	29 (56.9)	18 (58.1)	52 (55.9)
3	5 (9.8)	7 (22.6)	13 (14.0)
4	6 (11.8)	1 (3.2)	9 (9.7)
5≤	11 (21.6)	5 (16.1)	19 (20.4)
ISS, n (%)			
≤ 15	46 (90.2)	24 (77.4)	77 (82.8)
16≤ (polytrauma)	5 (9.8)	7 (22.6)	16 (17.2)
ICU Admission, n (%)			
Yes	5 (9.8)	4 (12.9)	11 (11.8)
No	46 (90.2)	27 (87.1)	82 (88.2)
HAI, n (%)	0	0	2 (2.2)
ICD-9 code: infection, n (%)	1 (1.96)	1 (3.53)	2 (2.2)
Positive Culture, n (%)	0	1 (3.2)	2 (2.2)
CVL insertion, n (%)	2 (3.9)	0	1 (1.1)
Mechanical Ventilation, n (%)	3 (5.9)	4 (12.9)	4 (4.3)
Elevated WBC count, n	1 (2.0)	0	2 (2.2)
Non-Proph Antibiotics, n (%)			
Yes	17 (33.3)	5 (16.1)	26 (28.0)
No	34 (66.7)	26 (83.9)	67 (72.0)

* Numbers may not sum to totals due to missing data. Column percentages may not sum to 100% due to rounding.

DISCUSSION

Suggestive Cushion Effect

Though no statistical significance can be made analyzing this data set, a particular trend in Table 3 can be suggestive of an already studied phenomenon. A 2003 by Arbabi et al. looked at the outcomes of trauma patients who had experienced motor vehicle accidents. The researchers noticed that patients with a higher BMI had lower ISS scores, meaning they had less severe traumatic injuries. More specifically, compared to lean patients, those with a greater BMI had significantly less abdominal injuries. Arbabi theorizes that the excess adipose tissue in these patients may offer individuals and protective barrier, or cushion, during trauma; hence labeling it the "cushion effect". Similar findings in children were found in the Brown 2006 cited in the introduction of this paper.

In Table 3, we have severe trauma and non-severe trauma based on ISS score stratified by BMI weight categories. The percentage of obese patients with an ISS over 16 was 9.8%, which was lower than overweight patients with severe trauma (22.6%) and normal weight patients (17.2%). Though more data would be needed to associate BMI with lower ISS scores, this is an interesting trend none the less that echoes the findings of the Arbabi study. Unfortunately, we did not collect any data on what kind of injuries our trauma patients experienced; therefore, we cannot make conclusions based on types of injuries between BMI categories.

Study Question

The goal of this study was to collect the number of HAIs, days of mechanical ventilation and days with a central venous line in our cohort and match that data with patient BMI percentiles. Unfortunately, there were not enough data in either of these variables to show any kind of significant statistical association.

Non-prophylactic Antibiotic Use

Data was collected on whether non-prophylactic antibiotics were used during the course of a patient's hospitalization. The rationale for the collection of this data was that patients receiving non-prophylactic antibiotics may indicate an infection diagnosis from the physician. Cefazolin (Ancef) was the most commonly used antibiotic for prophylaxis at DCMC, and that was excluded from the Pharmacy Department's cross reference of our study group with antibiotics prescribed during our cohort's hospitalization.

However, this was a simplistic approach to a complicated issue. Though some antibiotics may be used as prophylaxis in some cases, different clinicians may use them as first line treatment in other situations. Though Pharmacy detected if an antibiotic was used, teasing out whether it was used as prophylaxis would have required more time and resources. In its current form, the non-prophylactic antibiotics variable tells us very little.

Infection Risk Factors and BMI Percentiles

As described in the introduction, strong evidence in the literature points to an association between obesity and infection risk factors during hospitalization such as prolonged length of stay, prolonged mechanical ventilation and prolonged use of CVL. However, in this study, there was not enough data to make an association between these risk factors and BMI percentiles.

Infection Cases

The numbers of infections in this study were low, but there were two separate indicators for infection events; NHSN defined HAIs and ICD-9 codes for infections. In the end, there were only 3 patients with NHSN defined infections and 9 patients with ICD-9 infection codes in the same cohort. Both describe the event of an infection but they obviously resulted in very different counts. To understand this discrepancy, the role that each of these variables play in health care needs to be further described.

ICD-9 codes

International Classification of Diseases (ICD) Codes were developed by the World Health Organization as a list of nomenclature to describe medical diagnoses. Physicians assign diagnoses in the medical record then medical coders review the records after the patient is discharged and assign the appropriate codes to that patient's record. These codes are chiefly used for billing purposes, health insurance reimbursement and statistical reports by national agencies on morbidity and mortality.

The ICD-9 coding system is currently used in the United States and an updated, 10^{th} revision of the nomenclature list (ICD-10) is planned to be implemented in the near future. Although ICD-9 codes are available for clinical research their principle intent is to be used to classify morbidity data, primarily in inpatient and outpatient records and physician offices. The revisions to the

disease nomenclature over the years were made to accommodate the role ICD codes play in health care administration.

For retrospective clinical research, collecting ICD-9 codes is simple and easy because they are easily accessible. However, a number of studies have assessed the accuracy of these codes when compared to accepted surveillance definitions (Stevenson, 2008) (Sherman, 2006). They are unanimous in their conclusions that ICD-9 codes are an inaccurate system for disease surveillance. This is especially true for HAIs, as we will discuss.

Accuracy of ICD-9 codes for Infections

The lack of accuracy of ICD-9 coding used for surveillance purposes is nowhere more evident than in the case of Pennsylvania's HAI surveillance efforts in 2004. The state government mandated public reporting of HAIs by consolidating ICD-9 codes for all hospitals. After a year of using this method, state investigators noticed that there were nearly 10 times more infections with this system when compared to the previous year's surveillance system that used NHSN definitions (Pennsylvania, 2004).

When investigators in Pennsylvania applied NHSN definitions to the HAIs found using ICD-9 coding, they found that only 15% of HAIs that year could be considered actual HAIs (Julian, 2006). This overwhelming amount of error was attributed to a number of flaws with the ICD-9 coding system. For instance, medical coders can sometimes miscode patients that had no infections of any kind. Medical coders are also unable to discern the difference between an infection that originated in the community or in the hospital. They also do not have the training to interpret a positive microbial culture as an incidence of infection or colonization (Penn., 2004) (Brennan, 2005). Needless to say, after this discovery, the state of Pennsylvania understood that this system was not reliable and began using NHSN definitions to classify HAIs public reporting.

Looking more specifically at one ICD-9 code for infection, a study by Schweizer et al. in 2011 investigated the accuracy of ICD-9 coding as a tool to calculate the rate of methicillin-resistant *Staphylococcus aureus* (MRSA). This study began chiefly as a response to these codes being used by clinical researchers in the literature. The ICD-9 code the investigators focused on was the V09 code entitled "infection with drug-resistant microorganisms for identifying culture-proven MRSA infection". In a study spanning 6 years and involving 3 "geographically distinct"

hospitals, investigators compared positive cultures for MRSA during hospitalization (these were considered true cases of MRSA) with V09 code assignments. Of the 4,506 discharged patients who had the V09 code assigned, 20% had prior history of MRSA colonization or infection but did not have an incident MRSA infection and 49% had no record of MRSA infection during their hospital stay or the previous hospitalization. Investigators calculated the positive predictive value of the v09 code to be 31%. That means that this ICD-9 code correctly identified cases of MRSA only 31% of the time. Their data overwhelmingly showed that the ICD-9 coding system is not an appropriate tool to measure rates of MRSA infection.

Limitations with ICD-9 for HAI surveillance

A number of limitations exist with ICD-9 codes that make them unsuitable for tracking HAIs. Firstly, only the principle ICD-9 diagnoses codes are listed in a patient's record. The codes are ranked based on severity and costliness for treatment. Therefore, a patient with multiple complications may have had an HAI noted, but the infection was ultimately outranked when compared to more severe conditions.

Additionally, ICD-9 codes are only assigned after a patient has been discharged from the clinic. An infection that occurs during that stay could have happened during the hospital stay or in the community. Determining whether an infection is an HAI requires that the event occurred enough time into a hospital stay to be considered to have originated at the hospital. This time factor is completely absent with ICD-9 codes and leaves the setting of infection indeterminable (Kuehnert, 2005).

Furthermore, the difference between microorganism colonization and infection may not be distinguished. For example, a central venous catheter may be colonized and may show results on a growth plate, but, for there to be an infection, other conditions must be present in the patient such as fever, elevated white blood cell count, etc. Therefore, solely classifying an infection based on a positive culture can be inaccurate. If a medical coder observes that a positive culture was mentioned in a patient's medical record, they may jump to the conclusion that an infection had occurred. Issues such as this contributed to the discrepancies between true HAI surveillance and ICD-9 driven surveillance in Pennsylvania in 2004.

Even if coded accurately, a great limitation of ICD-9 coding stems from its dependence on physician diagnoses. Different physicians can interpret the same condition differently. It is for this reason that a set of criteria were created by the CDC/NHSN to make the determination of an HAI as objective as possibe.

NHSN definitions for HAIs

The state of Pennsylvania reversed its decision to use ICD-9 coding and began to use definitions from The National Healthcare Safety Network (NHSN), a division of the CDC, for HAI public reproting. Since 1988, NHSN has released criteria to guide infection control surveillance. The general definition for an HAI is an "adverse reaction to the presence of an infection agent or toxin" that is not "present or incubating at the time of admission". Criteria such as positive cultures 48 hours after admission give researchers a variable of time that increases the likelihood that the infection was contracted in the healthcare setting and not brought in from the community (Appendix A serves as an example of criteria for an NHSN defined HAI).

The people that determine if an HAI has occurred are the Infection Prevention Specialists in a hospital's Infection Control and Prevention Department. These people have special training to review the medical record and determine if a case meets an NHSN definition for an HAI.

Benefits of NHSN definitions

Surveillance has a number of benefits for Infection Prevention practice. With such consistent case definitions, baseline rates of infections can be established, clusters of infections can be identified, and the effect of prevention interventions can be assessed. Furthermore, comparisons can be made between hospitals, hospital units, groups of patients and providers (Yokoe, 1994).

However, a physician's diagnosis for infection may still be considered in an Infection Prevention Specialist's assessment. This presents one of the limitations of NHSN criteria for infections. As the NHSN guidelines state:

"For certain types of infection, a physician or surgeon diagnosis of infection derived from direct observation during a surgical operation, endoscopic examination, or other diagnostic studies ***or from clinical judgment*** *is an acceptable criterion for an HAI, unless there is compelling evidence to the contrary. For example, one of the criteria for SSI is ''surgeon or attending*

physician diagnosis.'' Unless stated explicitly, physician diagnosis alone is not an acceptable criterion for any specific type of HAI."

Limitation of NHSN definitions with the case of Ventilator-Associated Pneumonia

Ventilator-Associated Pneumonia (VAP) is an HAI which the NHSN currently classifies under Clinically-Defined Pneumonia (PNU1). It is one of the most difficult HAIs to identify (the full definition for a PNU1 is located in Appendix A) (Klompas, 2008). The NHSN definition for VAP requires abnormal temperature or WBC count, and ≥2 changes in pulmonary signs, such as worsening oxygenation, change in the character of secretions, or rales (Horan, 2008). This complex definition is time consuming to apply, primarily because it requires multiple subjective assessments by Infection Prevention Specialists. To be considered a VAP, an integral component of the criteria for PNU1 requires the interpretation of a chest x-ray for either 1 of the following: *new or progressive and persistent infiltrate, consolidation, cavitation, pneumatoceles (in infants <1 year old)*. This criterion needs to be met with 2 or more chest x-rays. Infection Prevention Specialists are not trained to read these x-rays and are therefore dependent on the assessment of physicians. The subjectivity and variability of a physician interpretation of a condition creates a drawback to NHSN definitions that mirror a limitation present in ICD-9 coding.

To highlight this limitation, a particular study analyzed the variability of physician diagnoses of VAP (Fagan, 1993). Researchers recruited 7 physicians to diagnose 84 patients with abnormal chest x-rays and purulent sputum. The true prevalence of VAP was determined by histological tests and quantitative bronchoscopy culture. Researchers found that the best physicians missed 28% of true VAP cases and the worst physicians missed 50%. All physicians misdiagnosed 20% of patients without VAP as having it. This study suggests that subjectivity is inherent in the diagnosis of pneumonia, especially when interpreting radiography. However, the objectivity that an NHSN strives for is diminished with the inclusion of physicians' inconsistent and subjective criteria for VAP classification.

It is important to further note that even when an HAI is being classified with the same NHSN definition, there may be little agreement. A study by Klompas in 2010 explores interobserver agreement for HAI sightings among physicians and Infection Prevention Specialists. The magnitude of interobserver agreement can be calculated with a Kappa statistic, which ranges

from 0 to 1, where 1 is when people are in perfect agreement and 0 where agreement is by chance (Viera, 2005). Klompas looked at the agreement among 4 reviewers at a certain hospital, 3 Infection Prevention Specialists and 1 physician for 50 possible cases of VAP. The study found that the reviewers agreed on 62% of the cases with a K statistic of 0.40. The authors discuss that the subjectivity inherent in the current NHSN definition for VAP does not allow for effective benchmarking of infection rates and presents a great limitation with these current guidelines.

Possible surveillance alternatives

Some recent research has explored ways to control for subjectivity in HAI case determination. Another study by Klompas in 2010 took the qualitative, subjective criteria in the NHSN definitions for VAP and substituted them with quantitative thresholds. For example, "worsening oxygenation" was redefined as a specific increase above the patient's baseline positive-end expiratory pressure. The very qualitative criteria of "presence of sputum purulence" was redefined as "≥25 neutrophils per low-power field seen on pulmonary secretion Gram stain". In addition, they completely eliminated NHSN criteria that could not be measured such as rales, dyspnea, cough, and delirium.

With their more objective definition for VAP, researchers scanned 459 patients on mechanical ventilation in medical and surgical ICUs. When compared to the NHSN definition that was normally being used by Infection Prevention, this pilot study found the sensitivity of their approach to be 95% and their positive predictive value to be 100%. Although more research is needed, investigators concluded that analyzing electronically-collected, quantitative data could save time and resources. It could potentially be an appropriate replacement to the chart review process done by Infection Prevention Specialists for every suspected HAI case.

Exploring new ways for objectifying infection surveillance was further described by a recent 2005 study by Haas et al. These investigators looked specifically at objectifying one of the most subjective elements of the VAP definition, the radiographic interpretation. Looking at the radiographic reports in the neonatal intensive care unit that were presented in free text, Haas et al. picked predetermined words and phrases that, if found in the reports, would be suggestive of pneumonia. This strategy detected 71% of cases found through NHSN defined surveillance. Though the positive predictive value was only 8%, when compared to the NHSN VAP

definition, meaning that the system only diagnosed 8% of the cases it chose correctly as VAP. But more impressive, this system had a specificity of 99%, meaning that almost all of the negative cases were actually negative.

In 2006, researchers in Denmark went further and initiated a VAP surveillance system that not only screened for specific phrases in radiologist reports, but also matched those possible cases with concurrent treatment with antimicrobial therapy. When this method was compared to traditional surveillance, it had a 81% sensitivity, detecting 81% of positive cases, and a positive predictive value of 100%. This meant that it never assigned VAP classifications to cases that were not VAP, as defined by NHSN (Leth, 2006).

Though these cases still depend on NHSN criteria to compare the results of their studies, it is a step in the right direction. Automating surveillance not only saves time and resources (freeing up Infection Prevention departments from hours of chart review) but it can potentially create objective definitions for infection. Such definitions could potentially offer research opportunities that span multiple medical centers without the limitation of having HAI classification being dependent on the training and experience of Infection Prevention Specialists at different hospitals.

Possible Pushback for Automated Surveillance

Allowing the determination of infection events in a hospital to be done through an automated system may leave Infection Prevention Specialists and hospital administrators uneasy. NHSN algorithms are designed to screen and eliminate large numbers of patients with a low likelihood of having true infections. Given the current realities of health care, this is a better system to have than an automated method that might detect more infections. This is particularly problematic for the hospital, especially when HAI reporting can be publicly scrutinized and HAIs have the possible consequence of financial penalties (Klompas, 2010). In fact, as of 2008, the Centers for Medicaid and Medicare (CMS) began instituting a policy where CMS would no longer reimburse hospitals for the cost of HAIs, forcing hospitals to cover the cost for treatment of HAIs.

Infections in this cohort

Though it is clear that there is a level of dependency on subjective interpretation in both ICD-9 and NHSN methods of surveillance, the CDC/NHSN definitions for HAIs are admittedly much more methodical and objective than ICD-9 coding. They are considered the gold standard in determining if HAIs have occurred. With the gold standard, my study found 3 HAIs. But, given what we know about HAIs this may or may not be a remarkable find.

A problem in hospital epidemiology is benchmarking with regards to acceptable or unavoidable rates of HAIs. Some experts, including the CDC, believe that all HAIs should be viewed as preventable and need to be driven to the least amount possible (Cardo et al, 2010). However, there is currently no study that shows what amount of HAIs is inherent to a hospital setting. Even the CDC admits:

"…additional research is needed to augment a limited understanding of the basic epidemiology of healthcare-associated pathogens (e.g. colonization and transmission dynamics), to inform development of rational prevention strategies."

Thus, it is possible that future studies may find that some HAIs are harder to prevent or may be all together unpreventable. We know that the cause of infections can be multifaceted. Even though one risk factor for infection is controlled, other risk factors may be unknown, unaccounted or currently immeasurable. For example, a surgeon's skill in the Operating Room may heavily influence a hospital's rate of surgical site infections (SSIs). But this clearly cannot be measured with the tools and knowledge we have at this time. At the same time, risk factors such as nurse compliance to appropriate hand hygiene practice and physician adherence to sterile bed-side procedures are known to influence infection rates as well. If the latter measurable risk factors are monitored in a hospital, then they can indicate if HAI rates are as low as they can be for that hospital.

The 3 HAIs in my study group may seem unimportant with tests that seek statistical significance; but if these cases are supplemented with information regarding other known infection risk factors, then these cases could be more serious than their few numbers may suggest. For instance, if compliance to infection prevention practices were acceptable and sustained

throughout the patients' hospitalizations, then these HAIs may have been caused by unknown factors or possibly been unpreventable. On the other hand, if these HAIs are associated with poor clinician adherence to infection control practices, then the cause of these infections may have been in the hospital's sphere of control and should be responded with appropriate hospital policies that target infection prevention practice.

LIMITATIONS

Medical chart errors for BMI percentile calculations

Though most of our 315 patients had height and weight variables for BMI percentile calculation, a large number did not. To ensure the greatest number of height variables we began our data collection on July 1, 2010, the day a hospital policy requiring height, along with weight, to be recorded on all admitted patients. However, of the 315 patients with a length of stay 2 days or over, 38% either did not have a height variable recorded or did not have a an appropriate height variable. When I used the CDC program that calculates BMI percentiles, some could not be calculated because of invalid height and weight combinations, labeling them as "biologically impossible". This is likely due to clinician error in recording the correct height

Steroid-use not monitored

In certain conditions such as trauma, inflammation can work against the body and cause tissue damage. Steroids, or corticosteroids, are drugs used to reduce the production of inflammatory chemicals in order to minimize tissue damage and reduce the activity of the immune system. As a consequence, this may leave the body more vulnerable to infection (Crohns and Colitis, 2012). Though the medical records were screened for history of immune-compromising conditions, steroid-use was not included in the screening process. This was not done because the study was limited in time and resources and lacked consultation from an infectious disease specialist. Though this would not have made a difference in the HAI counts from the Infection Prevention Department and the number of ICD-9 infection codes, it would certainly be a factor if researchers were interested in creating purely quantitative and objective definitions for infection, much like the Klompas study I previously discussed.

Future Research

At the end of this study, two testable questions come to mind. The study does not answer

whether obesity is associated with HAI risk. This study question may be better repeated in a case-control study. This study design may be more appropriate given the rarity of HAIs at DCMC. In such a study, a group of HAI cases would be compared to a group of patients without HAIs, but with similar injury severity, lack of comorbidities, medical device usage, etc. However, it would require many years of data to have a statistically significant outcome. Furthermore, the availability of patient height information for BMI calculation may not be consistently available and further limit usable data. Moreover, a multi-center study may bring the limitation of varying interpretations of NHSN definitions between multiple Infection Prevention Departments. Nevertheless, a case-control may begin showing if a relationship between BMI and HAIs exists.

But perhaps more pertinent to the HAI cases in this cohort, an investigation may be needed to further describe the clinical conditions that led to the 3 HAI cases at DCMC during my study period. If infection prevention practices were found not to be followed then an argument could be made for policy improvement. On the other hand, if infection control protocols were strictly followed then research, much like the attempts of this study, may be needed to discover new infection risk factors.

CONCLUSION

From this study, I cannot conclude that obesity is a risk factor for Hospital Acquired Infections (HAIs) in pediatric trauma patients; nor can I conclude that obesity increases the risk for known HAI risk factors such as prolonged hospitalization, mechanical ventilation and use of Central Venous Catheterization. However, the complicated nature of infectious disease epidemiology was further illuminated in this study, particularly with the sometimes subjective nature of the process of classifying HAIs.

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Appendix A *(Horan, 2008)*

Algorithms for clinically defined pneumonia (PNU1)

Radiology	Signs/Symptoms
Two or more serial chest radiographs with at least 1 of the following[1,2]: • New or progressive and persistent infiltrate • Consolidation • Cavitation • Pneumatoceles, in infants ≤1 year old NOTE: In patients without underlying pulmonary or cardiac disease (eg, respiratory distress syndrome, bronchopulmonary dysplasia, pulmonary edema, or chronic obstructive pulmonary disease), 1 definitive chest radiograph is acceptable.[1]	FOR ANY PATIENT, at least 1 of the following: • Fever (>38°C or >100.4°F) with no other recognized cause • Leukopenia (<4000 WBC/mm^3) or leukocytosis (≥12,000 WBC/mm^3) • For adults ≥70 years old, altered mental status with no other recognized cause *and* at least 2 of the following: • New onset of purulent sputum[3] or change in character of sputum[4] or increased respiratory secretions or increased suctioning requirements • New onset or worsening cough, or dyspnea, or tachypnea[5] • Rales[6] or bronchial breath sounds • Worsening gas exchange (eg, O_2 desaturations [eg, PaO_2/FiO_2 ≤240],[7] increased oxygen requirements, or increased ventilator demand) ALTERNATE CRITERIA, for infants ≤1 year old: Worsening gas exchange (eg, O_2 desaturations, increased oxygen requirements, or increased ventilator demand) *and* at least 3 of the following: • Temperature instability with no other recognized cause • Leukopenia (<4000 WBC/mm^3) or leukocytosis (≥15,000 WBC/mm^3) and left shift (≥10% band forms) • New onset of purulent sputum[3] or change in character of sputum,[4] or increased respiratory secretions or increased suctioning requirements • Apnea, tachypnea,[5] nasal flaring with retraction of chest wall or grunting • Wheezing, rales,[6] or rhonchi • Cough • Bradycardia (<100 beats/min) or tachycardia (>170 beats/min) ALTERNATE CRITERIA, for child >1 year old or ≤12 years old, at least 3 of the following: • Fever (>38.4°C or >101.1°F) or hypothermia (<36.5°C or <97.7°F) with no other recognized cause • Leukopenia (<4000 WBC/mm^3) or leukocytosis (≥15,000 WBC/mm^3) • New onset of purulent sputum[3] or change in character of sputum[4] or increased respiratory secretions or increased suctioning requirements • New onset or worsening cough or dyspnea, apnea, or tachypnea[5] • Rales[6] or bronchial breath sounds • Worsening gas exchange (eg, O_2 desaturations [eg, pulse oximetry <94%], increased oxygen requirements, or increased ventilator demand)