2018

Bronchiolitis in the Bluegrass: Epidemiology, Disease Burden and Resource Utilization at Kentucky Children's Hospital

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A paper submitted in partial fulfillment of the
Requirements for the degree of
Master of Public Health in the
University of Kentucky College of Public Health

By

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Lexington, KY

Final Examination:
CPH 202
November 27, 2018

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Abstract

Background: Every year Kentucky Children's Hospital (KCH) admits infants and toddlers with respiratory disease due to viral bronchiolitis. This disease is characterized by viral-induced inflammation and edema of the lower airways. The resulting disease is characterized by increasing mucus production, acute bronchospasm, necrosis of the respiratory epithelium and functional obstructive lung disease. Patients usually present with symptoms consistent with an upper respiratory tract infection, but can progress to marked respiratory distress and ultimately respiratory failure, as well as poor oral intake and dehydration. While Respiratory Syncytial Virus (RSV) is the pathogen classically described cause of viral bronchiolitis, other viruses have been known to cause this pathophysiology and symptoms. These viruses tend to cause disease during the colder months of the year, with a peak incidence between November and March. While there are no data regarding the disease burden for all viruses that can cause bronchiolitis, RSV infects approximately 90% of children in North America in the first two years of life with approximately half of those developing lower airway disease (Ralston, Lieberthal, & Meissner, 2015).

In 2014, consensus clinical practice guidelines (CPG) regarding the outpatient and inpatient management of RSV bronchiolitis were published in *Pediatrics*. These guidelines were published with the goal of standardizing care across the spectrum of clinical environments and avoid unnecessary and unwarranted therapies. Currently, no specific treatment exists for this condition outside of supportive care, including invasive respiratory support ranging from supplemental oxygen to extracorporeal membrane oxygenation, IV hydration and airway clearance (Ralston et al., 2015). The medical literature describes a cohort of patients who are more likely to require Pediatric Intensive Care Unit (PICU) admission and support with PICU modalities, which increases the likelihood of complications related to medical care (Haataja, 2018).

Objectives: The aim of this project was to quantify and categorize the disease burden associated with viral bronchiolitis at KCH. We examined all inpatient admissions of children ≤24 months to KCH with the diagnosis of viral bronchiolitis during two peak incidence seasons, defined as beginning November 1 and ending April 30. These admissions were evaluated based on the presence of significant co-morbid conditions and whether these conditions were associated with PICU admission. The project also assessed resource utilization across the inpatient hospital and determined which patients received no low-value treatments or diagnostics. These patients were defined as having received optimal care. The study also examined high flow nasal cannula (HFNC) utilization across the inpatient ward and PICU, including number of cases at KCH, number of transfers to the PICU and number of patients requiring immediate escalation or de-escalation in care.

Results: A total of 601 admissions for viral bronchiolitis were identified between the dates of peak incidence season, including 281 admissions between November 1, 2016 and April 30, 2017 as well as 320 admissions between November 1, 2017 and April 30, 2018. A total of 186 admissions were identified in which the patient had a history of prematurity and 37 admissions

in which the patient had congenital heart disease (CHD). Other co-morbidities like neuromuscular disease, immunodeficiency and tracheostomy with or without chronic mechanical ventilation were identified only in small numbers. The mean age at admission was 6.37 months (median 3.75 months) old with a median admission weight of 6.5 kg. The age and weight distribution was skewed towards younger patients. Average length of stay was 100.43 hours with an overall cost of almost $3.9 million to the institution for all admissions. Most admissions come through the KCH Pediatric Emergency Department (PED) but a larger proportion of patients came to KCH via transfers from community hospitals within the region. Bronchiolitis appeared to drive hospital capacity in the first four months of the season but appeared to contribute less in March and April. Prematurity and CHD were associated with Pediatric Intensive Care Unit (PICU) admission ($p=0.003$, $p=0.032$) and higher total hospital costs ($p=0.012$, $p=0.028$). Premature patients had a higher overall utilization of bronchodilator therapy ($p<0.001$), systemic corticosteroids ($p<0.001$), radiograph utilization ($p=0.015$) and viral testing ($p=0.007$) but no significant differences in antibiotic use compared to the rest of the patients ($p=0.705$). Patient with CHD had a higher overall utilization of bronchodilators ($p=0.007$), radiograph utilization ($p=0.001$) and viral testing ($p<0.001$) with no significant differences in antibiotic use ($p=0.61$) or corticosteroid use ($p=0.051$) compared with the rest of the patients. Utilization overall was more likely for PICU patients in all five metrics. Patients with no co-morbid conditions were considered to be optimal care candidates with patients who received no diagnostic and therapeutic intervention were considered to have received optimal care. Utilization in optimal care candidates versus patients who were not candidates from optimal care was significantly different in every metric except antibiotics among the 2017-18 cohort and not significantly different in every metric among the 2016-17 cohort. The proportion of patients who received optimal care increased from 32.1% in 2016-17 to 34.7% in 2017-18. A total of 167 admissions were placed on the therapy, of which 106 were started on HFNC on the inpatient ward and 60 in the PICU. Of those started on HFNC on the inpatient ward, transfers to the PICU decreased from 65% in 2016-17 to 41% in 2017-18. Of the 51 patients transferred to the PICU, seven (13.7%) were transferred back to the ward within 24 hours, six (11.7%) were escalated to non-invasive positive pressure ventilation (NIPPV) within 12 hours and another five (9.8%) were intubated and placed on mechanical ventilation within 12 hours.

Discussion and Conclusions: This analysis suggests that most of the utilization of resources and costs associated with inpatient care for bronchiolitis are diverted towards patients with significant co-morbid conditions and patients who require PICU admission. The ultimate goal will be to reduce resource utilization among optimal care patients and increase the proportion of patients needing fewer interventions. This will include annual data collection prospectively for each peak incidence season and an annual scorecard to present at institutional quality and safety (Q&S) meetings. A KCH respiratory work group has been formed to help create educational materials for KCH providers and staff on the correct assessment of an infant or toddler with respiratory distress as well as a review of the recent CPG. The work group will also provide outreach education to community and rural healthcare providers who may have limited experience in the care of pediatric patients. Data from county of origin will help direct this education to areas that send a larger volume of patients with bronchiolitis to KCH in order to optimize the impact. Multiple peak incidence seasons of inpatient data will help inform the creation of a new bronchiolitis protocol to guide inpatient management at KCH. HFNC data will continue to be collected during future peak incidence seasons in order to identify patient escalations, limit unnecessary transfers of patients to the PICU, and determine how KCH can best manage patients on HFNC outside of the PICU. The work group will also revise an existing HFNC management protocol in line with recent medical literature. Lastly, the work group will incorporate the KCH Pediatric Emergency Department (PED) and outpatient pediatric clinics in order to create an integrated project that spans the entire continuum of care. The project also fills a critical role in promoting best practices not only in the hospital, but within the community. KCH can play a leading role in promoting a competent, educated workforce both in the hospital and in the community. The hospital can also use the data to identify deficiencies both within the hospital and in the rural areas of Kentucky and create strategies to address them.

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List of Abbreviations

ANOVA: Analysis of Variance
ASD: Atrial Septal Defect
CHD: Congenital Heart Disease
CVC: Central Venous Catheter
CPG: Clinical Practice Guideline
ED: Emergency Department
ECMO: Extracorporeal Membrane Oxygenation
EMR: Electronic Medical Record
EMS: Emergency Medical Services
GA: Gestational Age
H&P: History and Physical
HFNC: High Flow Nasal Cannula
ICD-10: International Classification of Diseases (10th revision)
IRB: Institutional Review Board
IBU: Integrated Business Unit
IV: Intravenous
KCH: Kentucky Children's Hospital
MAR: Medication Administration Record
NICE: National Institute for Health and Care Excellence
NIPPV: Non-invasive Positive Pressure Ventilation
OVIHD: Office for Value & Innovation in Healthcare Delivery
PED: Pediatric Emergency Department
PICU: Pediatric Intensive Care Unit
PCR: Polymerase Chain Reaction
QI: Quality Improvement
RSV: Respiratory Syncytial Virus
TOF: Tetralogy of Fallot
UK: University of Kentucky
UTI: Urinary Tract Infection
VSD: Ventricular Septal Defect
WHO: World Health Organization

Introduction

Bronchiolitis is a condition caused by viral infection, traditionally with a virus called Respiratory Syncytial Virus (RSV). This disease commonly affects infants and toddlers by causing inflammation and edema of the lower airways. The disease pathology results in increased mucus production with associated bronchospasm, necrosis of the respiratory epithelium and functional obstructive lung disease (Kliegman, 2007). Patients usually present initially with symptoms consistent with an upper respiratory tract infection, but can progress over several days toward marked respiratory distress and ultimately respiratory failure as well as poor oral intake resulting in dehydration. This is due to progression of lower airway disease from mucus plugging in the medium sized lower airways, or bronchioles (Zitelli, 2002). In this way, it mimics a condition like asthma, with inflammation and acute bronchospasm of the medium sized bronchioles. Infants with bronchiolitis can present with nasal congestion and cough, but can quickly develop wheezing, rales, tachypnea and other signs of respiratory distress. Some infants require advanced respiratory support, via either high flow nasal cannula (HFNC), mechanical ventilation or even extracorporeal membrane oxygenation (ECMO).

RSV is the most frequent cause of bronchiolitis in infants and toddlers, accounting for 125,000 hospitalizations and 250 infant mortalities in the United States annually (Piedimonte & Perez, 2014). Approximately 90% of children in North America are infected with RSV at some point in the first two years of life with approximately half of those developing lower airway disease (Ralston et al., 2015). The hospitalization in the United States rate is 5.2 per 1000 children less than 2 years old with a healthcare cost of over $1.7 billion dollars annually (Ralston et al., 2015). The World Health Organization (WHO) estimates that RSV bronchiolitis accounts for more than 60% of all acute respiratory infections in children and over 80% of acute respiratory infections in infants less than one year of age (Piedimonte & Perez, 2014). The incidence of hospitalization is higher among infants under 60 days old (25.9 per 1000 children) and among premature infants under 30 weeks gestational age (18.7 per 1000 children) (Ralston et al., 2015).

Over the past decade, with the advent of direct fluorescent antibody and polymerase chain reaction (PCR) testing, pediatricians have been able to identify multiple different viruses that can cause bronchiolitis, including enterovirus, adenovirus, human metapneumovirus and others (Kliegman, 2007). There is no clear, compelling data regarding the disease burden for all viruses that can cause bronchiolitis, only for RSV, nor is there evidence that any particular virus causes a more serious infection (Ralston et al., 2015). This might suggest that the total burden of bronchiolitis as a disease, including non-RSV infections, is likely underestimated. These infections tend to have a peak incidence season during colder months, particularly between November and April in the United States, however they can be year-round in subtropical environments seen in places like Florida (Figure 1) (Ralston et al., 2015).

In 2014, a consensus clinical practice guideline (CPG) regarding the outpatient and inpatient management of bronchiolitis was published in *Pediatrics*. These guidelines stressed that bronchiolitis was primarily a clinical diagnosis, meaning that the diagnosis could be made based on clinical suspicion due to signs and symptoms and the patient's age (Ralston et al., 2015). Therefore, viral testing was deemed unnecessary and management of the disease was the same regardless of the viral etiology. The guidelines were also published with the goal of establishing a standard of care across the spectrum of clinical environments. Currently, no specific treatment exists for this condition outside of supportive care, including invasive respiratory support ranging from supplemental oxygen to ECMO, intravenous (IV) hydration and airway clearance via nasal suctioning (Piedimonte & Perez, 2014). The goal of supportive care is to keep the patient appropriately hydrated and avoid hypoxia. Treatments such as inhaled bronchodilators, systemic corticosteroids and antibiotics have previously been considered as possible therapeutic interventions. However, the guidelines explicitly recommend against the use of these therapeutics, concluding that they have minimal benefit in the treatment of bronchiolitis (Zorc & Hall, 2010); (King et al., 2004). Similarly, the guidelines recommend against obtaining diagnostic chest radiographs as x-rays do not change management of the disease and expose children unnecessarily to radiation (Zorc & Hall, 2010).

The medical literature describes a cohort of patients who are more likely to require Pediatric Intensive Care Unit (PICU) admission. These patients include ones with a history of prematurity, congenital heart disease (CHD), immunodeficiency, neuromuscular disease or patients with chronic respiratory failure requiring tracheostomy with or without chronic mechanical ventilation (Haataja et al., 2018); (Ralston et al., 2015). These patients may require more invasive respiratory support including HFNC, mechanical ventilation and ECMO. This in turn may lead to patients receiving other ancillary interventions, such as the above listed diagnostic and therapeutic modalities, as well as urinary catheter placement or central venous catheter placement. Support with these types of interventions increases the likelihood of iatrogenic complications related to medical care. The 2014 CPG excludes patients admitted to the hospital with any of these co-morbid medical conditions and those admitted to the PICU (Ralston et al., 2015). Therefore, patients excluded from the CPG are considered to be potential outliers who may need more aggressive care, including some of the treatment modalities that are considered low-value in bronchiolitis patients without significant co-morbidities. While there have been recent studies demonstrating the safety of HFNC outside of the PICU, its overall efficacy and specific titration parameters remain unclear and are often dependent on institutional practices (Franklin et al., 2018); (Kepreotes et al., 2017).

In order to reduce the use of these treatments and diagnostics in otherwise healthy infants with bronchiolitis, a collaborative quality improvement (QI) project used educational tools to reduce the use of low value therapies and diagnostic studies in treating infants and toddlers with viral bronchiolitis. Of the 21 centers that participated in the project, most identified as pediatric units within a larger hospital. With staff education, these centers were able to collectively reduce average bronchodilator use by 29%, reduce steroid use by 68%, reduce chest radiography use by 44% and noted a decreased hospital length of stay by five hours (Ralston et al., 2016). This QI project demonstrated that educational and outreach strategies can be employed to reduce utilization of resources for patients with viral bronchiolitis in the children's hospital and can be applicable to children's hospitals globally (Figure 2) (Ralston et al., 2016). In the United Kingdom, the National Institute for Health and Care Excellence (NICE) has implemented similar educational strategies and guidelines for care in the management of bronchiolitis and have seen compliance with the NICE guideline increase from 28% in its first year to 63% within 3 years (Breakell, Thorndyke, Clennett, & Harkensee, 2018). Patients who did not receive any of the described treatments or diagnostic studies are considered to have received optimal care in accordance with the CPG.

Present Study

Each year Kentucky Children's Hospital (KCH) admits infants and toddlers with respiratory disease due to bronchiolitis. These patients are admitted from locations throughout the Commonwealth of Kentucky and surrounding region. Many of these patients first come to medical attention in outpatient clinics, urgent care centers, community-based emergency departments (ED) or the KCH pediatric emergency department (PED). The clinical disease burden associated with bronchiolitis at KCH has been unclear. Along with the lack of knowledge of the demographics of this patient population, KCH has no recent data on utilization of therapeutic interventions such as bronchodilators, systemic corticosteroids, HFNC or antibiotics. Similarly, KCH has no recent data regarding utilization of diagnostic modalities like radiography and viral testing. While KCH created a HFNC protocol in 2013, it does not account for the new clinical guidelines or recently published studies outlining titration strategies or efficacy as no real true best practices exist (Miller, Gentle, Tyler, & Napolitano, 2018).

This project aimed to quantify the disease burden associated with bronchiolitis at KCH. This included identification of the sex, weight and age demographics of patients being admitted to KCH, co-morbid conditions of patients admitted with bronchiolitis, and utilization of low-value diagnostic and therapeutic interventions specifically discussed in the 2014 CPG. This study also benchmarked admissions against hospital capacity and evaluated total cost to the institution. The data collected in this study will inform the design and implementation of educational outreach to outlying rural communities that transfer patients to KCH as well as institutional education on the published CPG.

Methods

The core research group obtained approval from the Institutional Review Board (IRB) to collect retrospective data from the two most recent peak incidence seasons. Peak incidence season was defined as beginning on November 1 and ending April 30. Our team met with data analysts from the Office of Value & Innovation in Healthcare Delivery (OVIHD) to help obtain the data. The inclusion criteria were any child ≤24 months of age admitted to KCH with the diagnosis of viral bronchiolitis between November 1, 2016 and April 30, 2017 (represented as 2016-17), and between November 1, 2017 and April 30, 2018 (represented as 2017-18). All data were from the patient electronic medical record (EMR). Admissions for bronchiolitis were identified by admit ICD-10 diagnosis codes for viral bronchiolitis, viral respiratory disease or viral pneumonia. These patients were then screened for prematurity, CHD, neuromuscular disease, immunodeficiency, having a tracheostomy, and having a tracheostomy along with ventilator dependence. These conditions were also identified by International Classification of Diseases (ICD-10) diagnosis codes, but also by performing multiple keyword searches in the admission History and Physical (H&P) for common phrases to describe prematurity and for diagnosis-specific CHD, immunodeficiencies and neuromuscular diseases. Patient sex, as well as admission weight and age were also pulled directly from the patient chart flowsheets. Bronchodilator and steroid use were determined by search for physician orders for these medications as well as presence in the medication administration record (MAR). Comprehensive respiratory panels are used as diagnostic testing at KCH to identify the specific viral nucleic acids in nasopharyngeal secretions. The use of this test was identified by physician order and results obtained in the EMR. Admissions where chest radiography was performed were similarly identified by the presence of a physician order as well as a result posted in the EMR. To assess antibiotic usage, we identified patients who received antibiotics by physician order in the EMR, then searched all patients for secondary infections, including ICD-10 codes for pneumonia, urinary tract infection (UTI), otitis media, bacteremia, meningitis and tracheitis. Patients who received these antibiotics with these concomitant bacterial infections were considered to have appropriate use of antibiotics and were not considered as part of resource utilization for this metric. Admissions where patients without comorbidities received none of these treatments were considered to have received "optimal care" under the current CPG. Downstream PICU utilization metrics such as urinary catheter placement, central venous catheter (CVC) placement, escalation to non-invasive positive pressure ventilation (NIPPV) or mechanical ventilation were obtained by data analysts looking at EMR flowsheets and procedure notes. HFNC data were obtained through respiratory therapist orders and respiratory care flowsheets in the EMR. Total hospital costs and hospital length of stay were obtained by data analysts through the UK data warehouse and the Integrated Business Unit (IBU). Hospital capacity data for 2017-2018 was provided by the KCH Quality and Safety (Q&S) Committee.

Statistical analyses were performed by the principal investigator using IBM SPSS™ with assistance from the dedicated University of Kentucky (UK) Department of Pediatrics biostatistician. The data were described using descriptive statistics such as frequencies and percentages. Age, weight, length of stay and hospital costs were represented as median, mean, standard deviation and interquartile range. Admissions to UK were listed as frequency by location or point of origin. Comparison of co-morbid condition and PICU admission was performed using Chi-square analysis. Comparison of comorbid cohorts and length of stay and hospital costs were performed using analysis of variance (ANOVA) and non-parametric testing. Comparison of resource utilization between candidates for optimal care and non-candidates was performed using Chi-square analysis.

Results

Basic demographics

The data obtained yielded 601 admissions in both years, including 281 involving 259 patients in 2016-17 and 320 admissions involving 300 patients in 2017-18. Both years demonstrated a male predominance (55.9% and 59.7% of admissions, respectively (table 1). The mean age at admission was 6.37 and 6.05 months respectively with a median of 3.75 and 3.7 months (table2). This demonstrated a rightward skew on the distribution of admissions by age (figure 3), suggesting more admissions for children of younger age. Admission weight showed a less skewed distribution and difference between mean and median (table 2, figure 4). Mean length of stay was 100 hours in 2016-17 and 118 hours in 2017-18 (table 3). Average admission costs were $5,725.62 per patient with a total institutional cost of $1.61 million in 2016-17 and $7,053.55 per patient with a total cost $2.26 million in 2017-2018 (table 4). Therefore, the total hospital cost for the care of all inpatients at KCH was nearly $3.9 million dollars for both years combined.

A linear regression analysis showed a significant negative relationship between age and length of stay, with longer stays associated with younger age after removal of significant outliers greater than three standard deviations above the mean length of stay (R= -0.11, p=0.003) (figure 5). The negative relationship between length of stay and weight was even stronger (R= -0.19, p<0.001) (figure 6).

<u>Admissions to KCH</u>

When examining throughput into KCH, most admissions in both years (85.1% and 89.4%) were admitted through the KCH PED, with smaller numbers being directly admitted from an outside institution or clinic (figure 7). Looking at admissions through the PED specifically, both years showed differences in how they arrived in the ED. In 2016-17, 61.5% of PED admissions came to the PED from the community or a non-healthcare origin versus 40.2% in 2017-18. Overall 2017-18 shows more balance between patients that arrived from the community, versus patients transferred to the KCH PED from an outside institution or clinic/office (figure 8). Of all bronchiolitis admissions to KCH during both peak incidence seasons, 26.2% came from Fayette County with another 19.8% coming from the immediate neighboring counties: Scott, Bourbon, Clark, Madison, Jessamine and Woodford (figure 9). Heat maps, broken down by year also demonstrate an increasing number of admissions originating along the Interstate-75 corridor to the south of Lexington, especially Laurel, Knox and Whitley counties (figure 10). During the 2017-18 season, bronchiolitis admits rose and fell proportionally with the percentage of days KCH was above maximum bed capacity for November through February. However, for March and April, percent days above capacity rose despite decreases in bronchiolitis admissions, suggesting that the correlation falls off toward the end of the peak incidence season and other conditions account for the KCH inpatient census (figure 11).

Co-morbid conditions

The data search yielded 186 premature patients admitted to KCH with bronchiolitis. We stratified these patients by season and by degree of prematurity. In 2016-17, 21% of admissions (n=59) were identified as being between 31 and 36 weeks gestational age (GA) and 6.8% of admissions (n=19) 30 weeks GA or under. In 2017-18, 21.6% of admissions (n=69) were identified between 31 and 36 weeks GA and 12.2% of admissions (n=39) were 30 weeks GA or under (figure 12). Thirty-seven patients were identified with CHD, with the specific type of disease shown here (figure 13). The most frequent types of CHD are ventricular septal defects (VSD n=9), atrial septal defects (ASD n=6) and Tetralogy of Fallot (TOF n=5). Premature patients overall were more likely to require admission to the PICU compared to non-premature patients (p=0.003). Patients with CHD were similarly more likely to require PICU admission (p=0.032) (table 5). Our population search yielded low numbers of admissions with tracheostomy (n=5), tracheostomy with ventilator dependence (n=2) and immunodeficiency (n=5) so statistical analysis was deferred on these admissions. Immunodeficiency diagnoses included two admissions of patients with 22q11 deletion and three admissions of the same patient with α-1 antitrypsin deficiency. No patients with neuromuscular disease were admitted in either season. Using one-way ANOVA, there were significant differences in mean length of stay between infants and toddlers born at term, born between 31 and 36 weeks GA and born at or before 30 weeks GA (p=0.002) (table 6). This analysis was performed after removing significant outliers greater than three standard deviations beyond the mean. Post hoc analysis shows a significant difference between length of stay of term children versus premature children ≤30 weeks GA (p=0.01). The difference in length of stay between term children versus children 31 and 36 weeks GA was not statistically significant (p=0.058). There are also significant differences between each range of prematurity in terms of hospital costs as well (p=0.012) but no significant differences in PICU costs (p=0.08) (table 7). Admissions with CHD do not have significant differences in length of stay compared to admissions who do not have CHD (p=0.063). However, total hospital costs are significantly higher in patients with CHD (p=0.028) with no significant differences in PICU costs (p=0.419) (figure 14, table 8).

Resource utilization

Part of the analysis with resource utilization includes identification of use in the entire cohort as well as a subgroup that has no comorbid conditions or risk factors that would prompt exclusion based on the CPG. Patients without co-morbid conditions were considered optimal care candidates. These patients truly received optimal care if they did not get any of the two diagnostic studies or the three therapeutic interventions. Data analysis identified 193 candidates in 2016-17 and 199 candidates in 2017-18 for bronchiolitis optimal care, meaning they received none of the five diagnostic and therapeutic interventions specifically discussed in the CPG. Our analysis looked at bronchodilator use, systemic corticosteroid use, antibiotic use, chest radiograph use and viral testing use.

We identified 148 admissions where bronchodilators were administered. This includes 65 admissions in 2016-17 and 83 admissions in 2017-18. The overall gross utilization was 24.6% of all admissions. Patient received anywhere from one to 23 doses. More doses were associated with a longer length of stay and increased hospital costs (p<0.001 for both) (figure 15). However, utilization and number of doses went down among the optimal care cohort (figure 15). Bronchodilator utilization among optimal care candidates was 19.9% for both seasons combined (20.2% in 2016-17 and 19.6% in 2017-18). When comparing bronchodilator utilization between optimal care candidates and the rest of the patients, utilization was significantly different in the 2017-18 season (p=0.001) and overall across both seasons (p<0.001), and not significantly different in 2016-17 (p=0.085) (table 9). When comparing bronchodilator use between optimal care candidates and premature patients and between patients with CHD, utilization in both groups with co-morbid conditions was higher (36%; p<0.001, 32.4%; p<0.001). Statistical analysis yielded similar findings for corticosteroid use, where we identified an overall utilization of 16.8% (20.7% in 2016-17 and 13.1% in 2017-2018). Steroid use among the optimal care cohort in 2016-17 was not significantly different when compared to the remaining patients (p=0.313) but was significantly different in 2017-18 (p<0.001) and overall (p<0.001) (table 10). Comparison of corticosteroid utilization among optimal care candidates with premature infants shows significantly higher utilization among the premature group (32.8%, p<0.001). A comparison of corticosteroid utilization between optimal care candidates and CHD approached statistical significance (29.7%; p=0.051). A total of 209 patients received antibiotics in both seasons for a gross utilization of 34.7%. However only 111 of optimal care candidates received antibiotics but did not have an identifiable bacterial infection. A total of 120 infections were identified in 98 patients. Infections identified include a large proportion of bacterial pneumonia and otitis media (figure 16). After removing patients with bacterial infections, a utilization rate overall of 21.9% was calculated. When optimal care candidates were compared to the remaining cohort as well as to premature patients (23.9%; p=0.71) and patients with CHD (17.9%; p=0.61), no significant differences were noted, suggesting that antibiotic use was similar across the different co-morbid groups (table 11).

Similar analyses were performed for chest radiograph utilization and for viral testing. A total of 299 patients received chest radiographs with a gross utilization of 49.7%. Within the optimal care group, total utilization was 45.7%. Utilization between optimal care candidates and the rest of the cohort was significantly different overall (p=0.006) and in 2017-18 (p=0.007) but not significant in 2016-17 (p=0.292). Utilization between optimal care candidates and premature and CHD patients is statistically significant (56.5%, p=0.015; 73%, p=0.001) (table 12). Viral panel testing yielded multiple viruses isolated in children with viral bronchiolitis. In 2016-17, 82 viral tests were performed with 114 viruses identified (figure 17), while in 2017-18 110 viral tests with 126 viruses identified (figure 18). RSV was the most commonly isolated virus with rhinovirus/enterovirus also being identified frequently. Utilization among optimal care candidates was 29.1% overall (29.5% in 2016-17 and 28.6% in 2017-18). Compared to the remaining cohort, there was significantly lower utilization in optimal care patients overall (p=0.004) and in 2017-18 (p=0.006), with no significant differences in utilization between groups in 2016-17 (p=0.254) (table 13).

<u>PICU and HFNC data</u>

A total of 168 admissions in both seasons to the PICU were identified. Of those, 101 were initially admitted to the PICU and 67 were initially admitted to the pediatric ward and ultimately transferred to the PICU for presumably worsening status (table 14). Of these 168 admissions, 20 patients required escalation to NIPPV for respiratory support, 47 required intubation and mechanical ventilation. Ten patients were placed on both modalities. Patients had longer lengths of time on mechanical ventilation with increasing age (R=0.39, p=0.007) (Figure 19). Patients with prematurity and CHD were more likely to have PICU admission compared to patients without those co-morbidities (p=0.003, p=0.032) (table 15). Overall PICU admissions had higher rates of utilization than non-PICU admissions across the board in all five resource utilization metrics (figure 20).

HFNC use was identified in 166 patients in both seasons. A total of 22.8% of admissions in 2016-17 and 31.9% in 2017-18 were placed on HFNC. Approximately two-thirds of these patients were initially admitted to the inpatient ward while the remaining one-third were admitted to the PICU. Of the patients on HFNC admitted to the inpatient ward, 65% in 2016-17 and 41% in 2017-18 ultimately required transfer to the PICU. A total of 19% and 7.4% of these PICU transfers in each season tolerated de-escalation of care and were able to transfer back to the inpatient ward within 24 hours. However 6 patients (11.3%) total in both seasons required escalation to NIPPV within 12 hours and 5 patients (9.4%) were intubated and placed on mechanical ventilation within 12 hours (figure 21). The mean length of stay, time on HFNC or hospital costs for patients on HFNC were not significantly different whether patients were admitted to the PICU or ward initially (table 16).

Discussion

<u>Bronchiolitis epidemiology</u>

Bronchiolitis is a very common disease in infants and toddlers, and providing the appropriate standard of care reduces iatrogenic complications from treatments and diagnostics, reduces family confusion with disease course and treatment and can reduce costs for the institution, families and insurance companies (Mussman et al., 2018). In order to reduce costs related to unnecessary care, multiple institutions have implemented an optimal care model, which tracks utilization of resources and identifies patients who have received appropriate care (Ralston et al., 2016). In order to achieve this goal at KCH, the appropriate patient population must be identified and education be provided to KCH staff as well as emergency medical service (EMS) providers and community ED providers who ultimately transfer patients to KCH for inpatient care. These data identify the total number of admissions at KCH for two peak incidence seasons, as well as where in the Commonwealth of Kentucky these admissions came from. The data also demonstrated that the KCH PED and was the primary point of entry into the hospital and therefore is often the first location to provide medical care for children with bronchiolitis. UK pediatric clinics affiliated with UK and KCH also serve as a first location at which care was provided. Therefore including the PED and UK pediatric clinics in an ongoing project will be necessary as the standard of care can be established at the initial location where care is provided. The PED and UK pediatric clinics are also a critical source of data as both practice settings serve as a filter for patients into the hospital, while discharging others home without inpatient admission. Any further analysis of resource utilization for bronchiolitis patients at KCH must include both the PED and UK pediatric clinic system. Inclusion of these practices will allow the institution to provide a critical public health service of educating the affected population, in this case families of children with bronchiolitis, on how to properly care for children with this disease as well as develop strategies that support patient families who caring for children with bronchiolitis (CDC, 2018).

The data on county of origin demonstrated that slightly less than half of bronchiolitis admissions came from Fayette County and the immediate surrounding counties. This means that over half of admissions came from more distant counties that have EMS and community ED personnel with limited experience in the care of pediatric patients. Knowing the distribution of counties where admissions to KCH originate informs how the institution can provide outreach and education to these providers. This is especially true of counties to the southeast of Lexington, which can be very remote from Interstates 75 or 64. Therefore, these counties may not have the immediate capability to promptly transfer patients from their community health care facilities to KCH, and therefore will have to shoulder the burden of an initial assessment and stabilization of these patients. KCH has a critical public health role in helping train competent public and personal healthcare workforce to care for children with bronchiolitis, and serving as a resource to improve the effectiveness, accessibility and quality of care provided at these outside institutions (CDC, 2018). Experienced providers from KCH ought to serve in a leading role in the education of rural community providers in how to care for bronchiolitis patients. This includes initial assessment of an infant or child in respiratory distress and a thorough review of the CPG. The PED also has a role in providing guidance away from low value therapies to outside institutions when they call for transfer.

Resource Utilization at KCH

Analysis of the data suggests that the bulk of resource utilization goes toward patients with significant co-morbid conditions such as prematurity and congenital heart disease. Resource utilization is also directed toward patients admitted to the PICU as well, and the data suggests that the presence of co-morbidities makes PICU admission more likely. Of the patients without co-morbidities, there appears to be less overall utilization in 2017-18 versus 2016-17. The overall number of patients who received true optimal care was 32.1% of candidates in 2016-17 and 34.7% in 2017-18. The highest utilization overall appears to be chest radiography at 46.6% and 44.7% in each year (figure 22). The lowest overall utilization appears to be steroids at 20.7% and 13.1% each year (figure 22). Future directions suggest these utilization rates can be benchmarked against comparable institutions in order to establish the opportunity for improvement (S. Ralston, Parikh, & Goodman, 2015). Therefore, educational material for KCH pediatric providers, nurses and staff is also critical. This includes a thorough review of the CPG, as well as review of proper nasal suctioning technique, and proper assessment of bronchiolitis patients for signs of deterioration. These signs include worsening work of breathing, hypoxia and dehydration. Along with education, creation of a bronchiolitis protocol to standardize care for all patients will be essential for inpatients at KCH going forward. Comparison of resource utilization during peak incidence and non-peak incidence seasons may help determine which resources are used more in the winter when hospital census due to viral bronchiolitis tends to be highest and inform the institution on what staff, equipment and other resources need to be available at specific times of the year. (Mittal et al., 2014)

<u>HFNC use at KCH</u>

HFNC use in patients with viral bronchiolitis remains a challenge to KCH as there are no clear guidelines on its efficacy or use. While HFNC has long been considered a PICU modality, its safety for use outside of the PICU has been demonstrated at other institutions (Franklin et al., 2018); (Kepreotes et al., 2017). Tracking admissions on HFNC to the PICU versus inpatient ward may be helpful in identifying deficits and strengths in the institution's overall investment in resources and training for staff. Tracking escalation and de-escalation metrics will be useful. Escalation metrics include patients started on HFNC on the inpatient ward and subsequently transferred to the PICU for more aggressive care and patients requiring escalation to NIPPV or mechanical ventilation within four hours and 12 hours. Patients requiring intubation within one hour of arrival to the PICU suggest an actively decompensating patient and require individual root cause analysis to determine what signs of worsening respiratory failure were missed on the ward. The de-escalation metrics to track include transfer back from the PICU to the inpatient ward within 24 hours, which suggests that the patient was able to come off HFNC quickly and may suggest overly aggressive titration of flow and oxygen levels of outside of the PICU. Along with summary review of these metrics, education to a specific cohort of the KCH nursing and respiratory therapy (RT) staff selected to take care of patients with viral bronchiolitis during peak incidence season may improve nursing and RT comfort with assessing respiratory distress and would potentially prevent unnecessary escalation and identify children who are truly getting worse and need transfer to the PICU. Such information could inform KCH to create a respiratory ward during peak incidence season, so that all respiratory patients are close together in proximity. This will help reduce the times between assessments by trained providers and staff. This will help especially after hours, when resident physician providers and RT staff are primarily responsible for serial assessments of these patients. These future directions fulfill a public health service of creating policies within the largest children's hospital in this region to support these patients in the safest and most effective way. An institution like KCH being heavily involved in bronchiolitis education and outreach both in and outside of the hospital, outpatient clinics, PED, EMS first-responders and outlying community institutions can also empower stakeholders to advocate for resources for these patients, both within the public health infrastructure but also advocate for policy changes at the state and local governmental level (CDC, 2018).

The KCH Respiratory Work Group

In conclusion, review of these data as well as future prospective data collection can have major implications on the management of bronchiolitis at KCH. While the retrospective data collected was important for identifying baseline demographics, co-morbidities and origin of patients, continuous data collection per peak incidence season will be essential for ongoing QI in order to further streamline care. An IRB application is currently being written to perform yearly data collection prospectively. This data will be reported annually at KCH Q&S meeting. In order to ensure ongoing success of this project, the KCH respiratory work group was formed in 2017 and consists of physicians, nurses and respiratory therapists employed at UK and KCH. The work group has multiple roles within KCH in regards to respiratory care for hospitalized children. One of the goals of the work group will be to provide didactic education, develop web-based modules for staff education and to collect and present data for each peak incidence season in regards to bronchiolitis. The work group will also lead outreach education to community partners.

In order to ensure this ongoing project covers all areas with care, physician champions from the PED as well as UK outpatient pediatric clinics will join the work group and participate in ongoing data collection and education in their respective clinical areas as well as outreach to community providers. Along with education for the community and KCH staff, the work group will also be responsible for the creation and revisions of a KCH viral bronchiolitis protocol with the goal of streamlining and standardizing management across different locations within the hospital. The work group has also been tasked to revise an existing HFNC based on the most up to date literature and track escalation and de-escalation metrics.

To determine which metrics are important the work group created the viral bronchiolitis seasonal scorecard (figure 23). This will serve as an easy reference to look at resource utilization among optimal care candidates and HFNC metrics. Benchmarks will need to be created based on data from comparable outside institutions involved in the AAP Bronchiolitis Quality Improvement Project as well as an achievable benchmark of care derived from our retrospective institutional data (Mittal et al., 2014). HFNC benchmarks will be set based on institutional data since no national benchmarks exist. The respiratory work group will be responsible for creating and maintaining the scorecard through each peak incidence season. The work group will also consider other metrics, such as time to initiation of enteral feeding, feeding tube placement and the incorporation of bronchiolitis scoring into regular assessments. These interventions can make KCH a community and national leader in the care of infants and toddlers with bronchiolitis and can serve as a potential model for other institutions throughout the country and world.

References

Breakell, R., Thorndyke, B., Clennett, J., & Harkensee, C. (2018). ***Reducing unnecessary, chest X-rays, antibiotics and bronchodilators through implementation of the NICE bronchiolitis guideline.*** *Eur J Pediatr, 177*(1), 47-51. doi:10.1007/s00431-017-3034-5

CDC. (2018, June 2018). **The Public Health System & the 10 Essential Public Health Services**. Retrieved from https://www.cdc.gov/stltpublichealth/publichealthservices/essentialhealthservices.html

Franklin, D., Babl, F. E., Schlapbach, L. J., Oakley, E., Craig, S., Neutze, J., . . . Schibler, A. (2018). **A Randomized Trial of High-Flow Oxygen Therapy in Infants with Bronchiolitis**. *N Engl J Med, 378*(12), 1121-1131. doi:10.1056/NEJMoa1714855

Haataja, P., Korhonen, P., Ojala, R., Hirvonen, M., Korppi, M., Gissler, M., . . . Tammela, O. (2018). **Hospital admissions for lower respiratory tract infections in children born moderately/late preterm**. *Pediatr Pulmonol, 53*(2), 209-217. doi:10.1002/ppul.23908

Kepreotes, E., Whitehead, B., Attia, J., Oldmeadow, C., Collison, A., Searles, A., . . . Mattes, J. (2017). **High-flow warm humidified oxygen versus standard low-flow nasal cannula oxygen for moderate bronchiolitis (HFWHO RCT): an open, phase 4, randomised controlled trial.** *Lancet, 389*(10072), 930-939. doi:10.1016/s01406736(17)30061-2

King, V. J., Viswanathan, M., Bordley, W. C., Jackman, A. M., Sutton, S. F., Lohr, K. N., & Carey, T. S. (2004). **Pharmacologic treatment of bronchiolitis in infants and children: a systematic review**. *Arch Pediatr Adolesc Med, 158*(2), 127-137. doi:10.1001/archpedi.158.2.127

Kliegman, J., Behrman, Stanton. (2007). *Nelson Textbook of Pediati* (18th ed.). Philadephia, PA: Saunders.

Miller, A. G., Gentle, M. A., Tyler, L. M., & Napolitano, N. (2018). **High-Flow Nasal Cannula in Pediatric Patients: A Survey of Clinical Practice**. *Respir Care, 63*(7), 894-899. doi:10.4187/respcare.05961

Mittal, V., Darnell, C., Walsh, B., Mehta, A., Badawy, M., Morse, R., . . . Kahn, J. (2014). **Inpatient bronchiolitis guideline implementation and resource utilization**. *Pediatrics, 133*(3), e730-737. doi:10.1542/peds.2013-2881

Mussman, G. M., Lossius, M., Wasif, F., Bennett, J., Shadman, K. A., Walley, S. C., . . . Ralston, S. L. (2018). **Multisite Emergency Department Inpatient Collaborative to Reduce Unnecessary Bronchiolitis Care**. *Pediatrics, 141*(2). doi:10.1542/peds.2017: 0830

Piedimonte, G., & Perez, M. K. (2014). **Respiratory syncytial virus infection and bronchiolitis**. *Pediatr Rev, 35*(12), 519-530. doi:10.1542/pir.35-12-519

Ralston, S., Parikh, K., & Goodman, D. (2015). **Benchmarking Overuse of Medical Interventions for Bronchiolitis**. *JAMA Pediatr, 169*(9), 805-806. doi:10.1001/jamapediatrics.2015.1372

Ralston, S. L., Garber, M. D., Rice-Conboy, E., Mussman, G. M., Shadman, K. A., Walley, S. C., & Nichols, E. (2016). **A Multicenter Collaborative to Reduce Unnecessary Care in Inpatient Bronchiolitis**. *Pediatrics, 137*(1). doi:10.1542/peds.2015-0851

Ralston, S. L., Lieberthal, A. S., & Meissner, H. C. (2015). Ralston SL, Lieberthal AS, Meissner HC, et al. **Clinical Practice Guideline: The Diagnosis, Management, and Prevention of Bronchiolitis.** Pediatrics. 2014;134(5):e1474-e1502. *Pediatrics, 136*(4), 782. doi:10.1542/peds.2015-2862

Zitelli, D. (2002). *Atlas of Pediatric Physical Diagnosis* (4th ed.). Philadelphia PA: Mosby.

Zorc, J. J., & Hall, C. B. (2010). **Bronchiolitis: recent evidence on diagnosis and management**. *Pediatrics, 125*(2), 342-349. doi:10.1542/peds.2009-2092

Biosketch

Dr. Ashwin Krishna is an Assistant Professor in the Division of Pediatric Critical Care Medicine, Department of Pediatrics, at the University of Kentucky College of Medicine, Kentucky Children's Hospital. He received a Bachelor of Arts in Philosophy and Biology at Washington University in St Louis, Missouri in 2002 and then graduated from the University of Tennessee Health Science Center, College of Medicine in Memphis, Tennessee in 2007. He completed his residency in pediatrics at Levine Children's Hospital, Carolinas Medical Center in Charlotte, North Carolina and Pediatric Critical Care Fellowship at Vanderbilt University, Monroe Carrell Jr. Children's Hospital, in Nashville, Tennessee. He is board certified in general pediatrics and board-eligible in pediatric critical care. Dr. Krishna is director of Respiratory Care Services at the Kentucky Children's Hospital Pediatric Intensive Care Unit. He is a fellow in the American Academy of Pediatrics (AAP) and a member of the Society of Critical Care Medicine (SCCM).

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Appendix

Figure 1

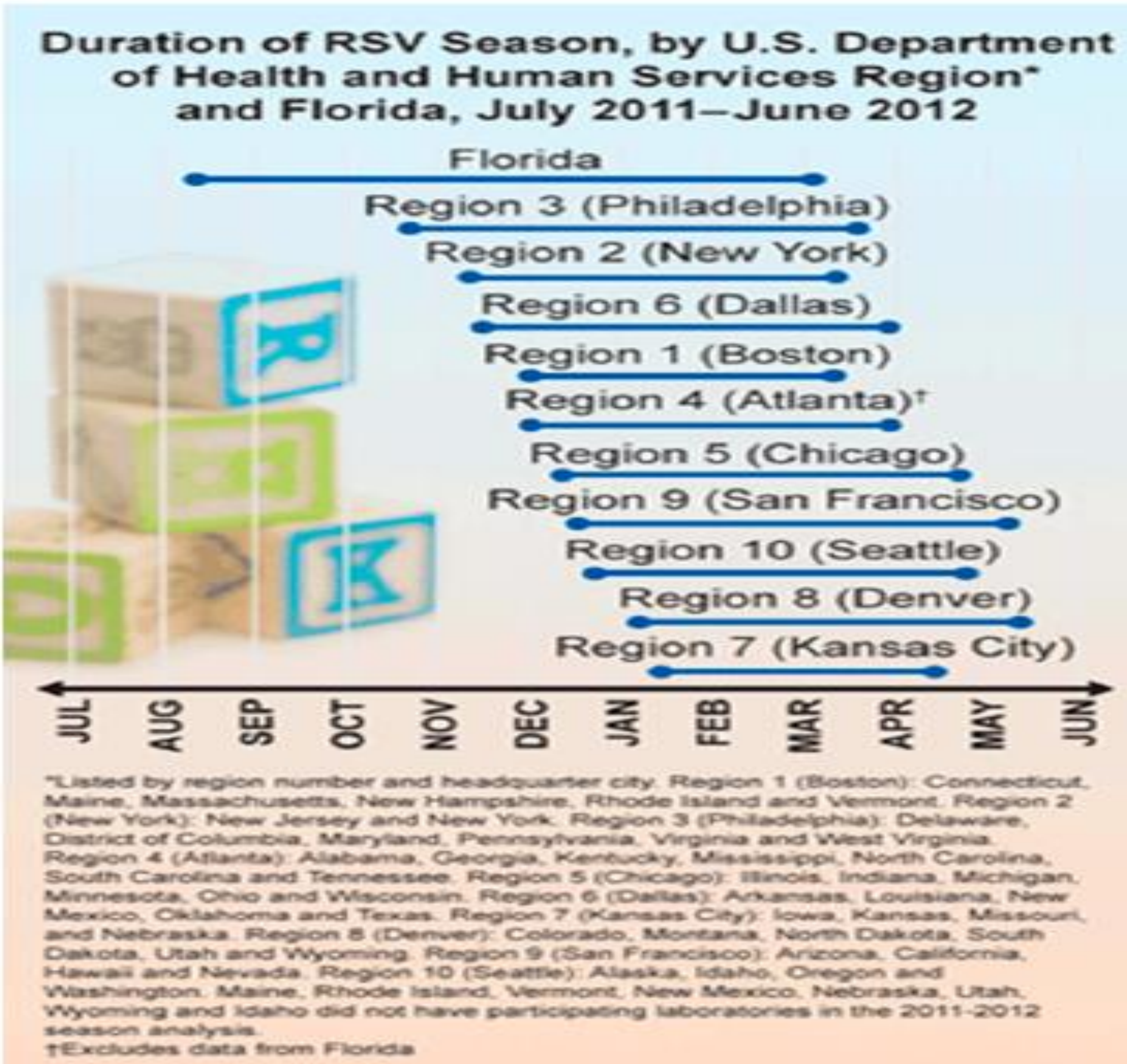
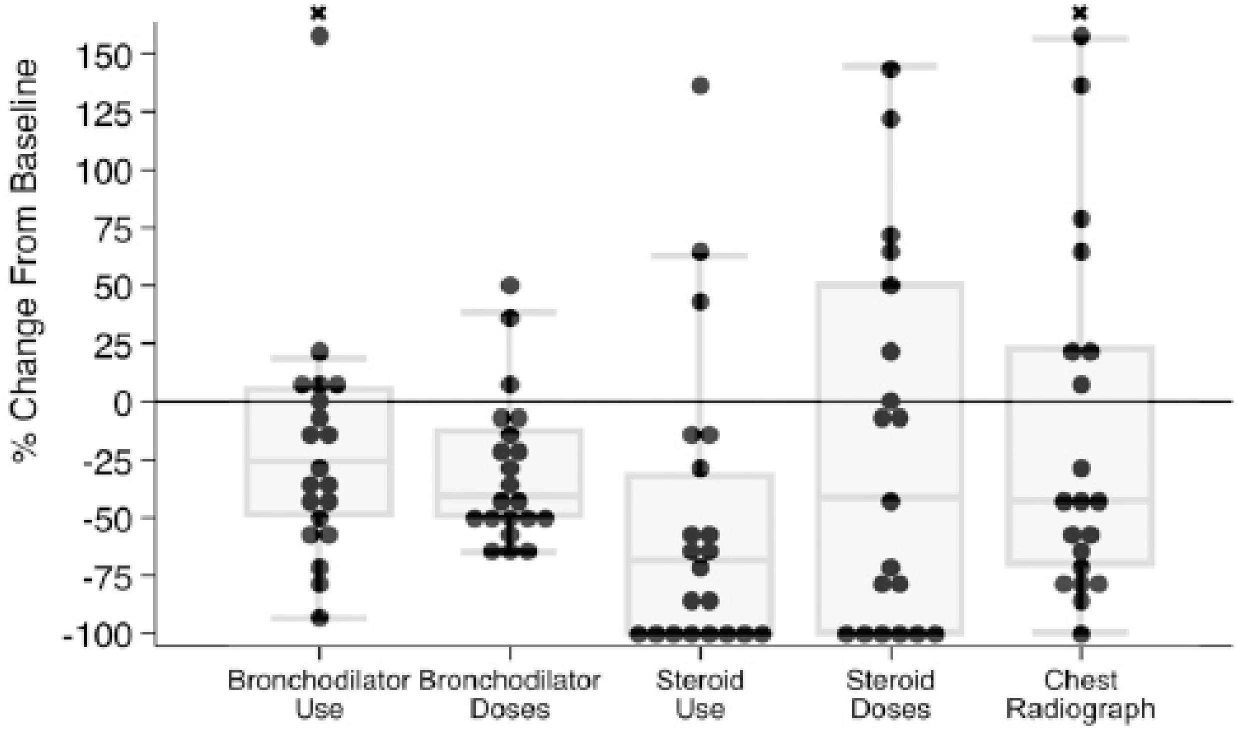


Figure 2



Note: Outlier values over 150% are represented as X in the top row of values (222% increase for one site in bronchodilator use, 174% increase for one site in chest radiography use)

FIGURE 1

Percent change from baseline for overuse metrics by site, median, and interquartile range. Outlier values >150% are represented as X in the top row of values (222% increase for 1 site in bronchodilator use, 174% increase for 1 site in chest radiography use).

Table 1

GENDER

ADMT_YEAR			Frequency	Percent
2016-2017	Valid	F	124	44.1
		M	157	**55.9**
		Total	281	100.0
2017-2018	Valid	F	129	40.3
		M	191	**59.7**
		Total	320	100.0

Bronchiolitis Admissions to KCH by Sex

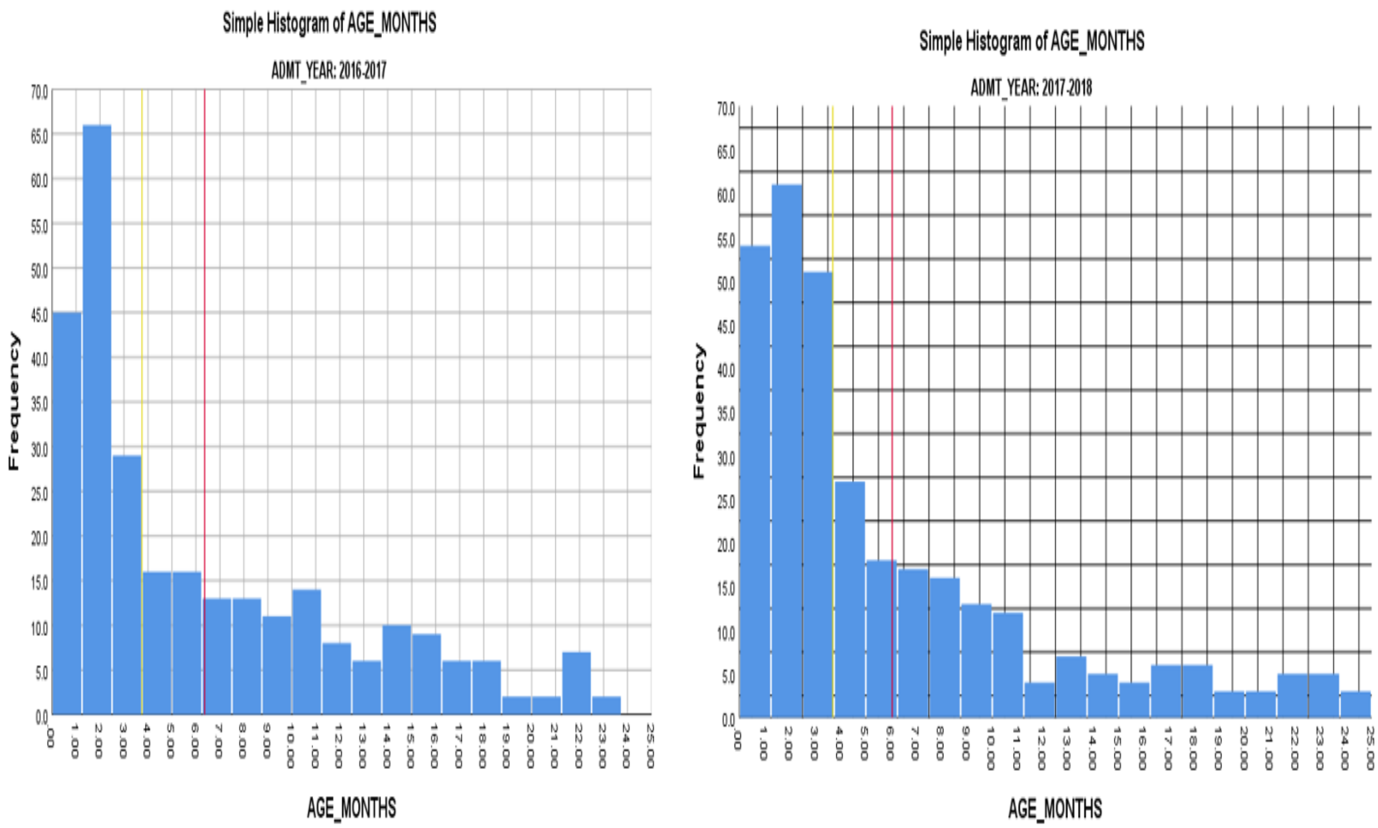
Table 2

Statistics

ADMT_YEAR			AGE_MONTHS	WEIGHT_KG
2016-2017	N	Valid	***281***	***281***
	Mean		**6.37**	**6.53**
	Median		**3.75**	**6.00**
	Std. Deviation		5.97	2.80
	Percentiles	25	1.60	4.29
		50	3.75	6.00
		75	10.24	8.61
2017-2018	N	Valid	***320***	***320***
	Mean		**6.05**	**6.29**
	Median		**3.70**	**5.71**
	Std. Deviation		5.93	2.47
	Percentiles	25	1.71	4.37
		50	3.70	5.71
		75	8.34	7.92

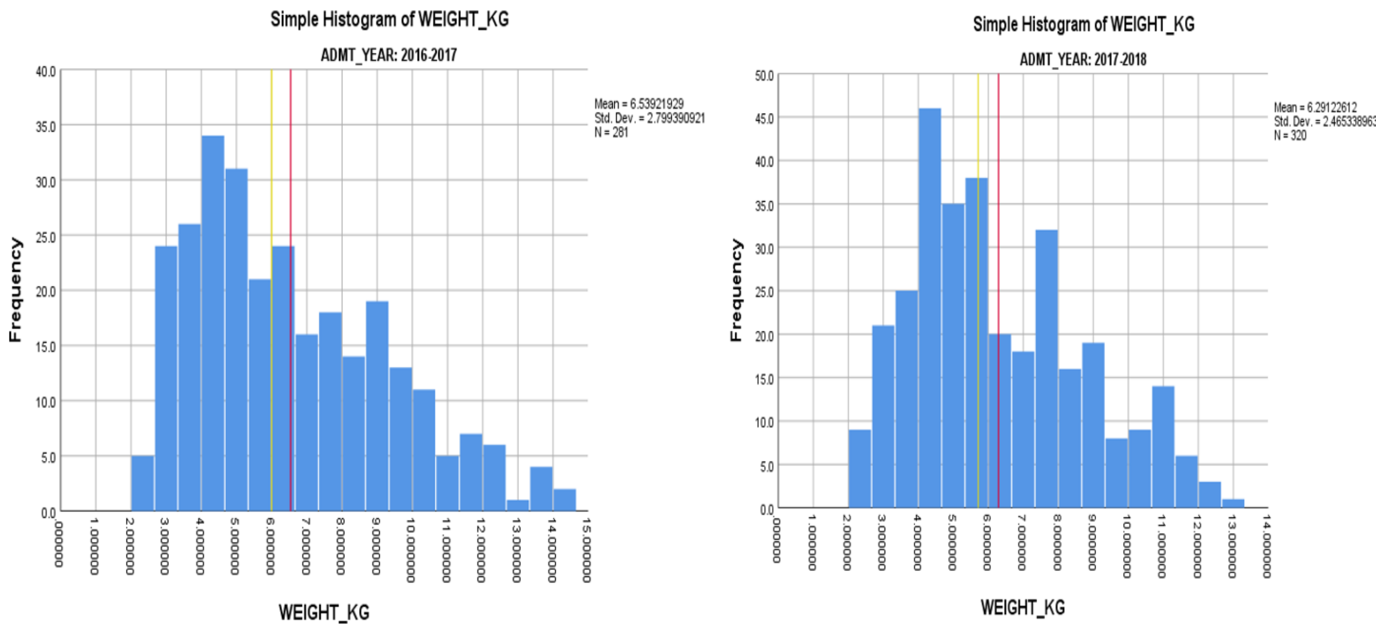
Bronchiolitis admission descriptives: Age (in months) and Weight (in Kg)

Figure 3



Histogram with frequency of admissions by age (in months) in 2016-2017 and 2017-2018

Figure 4



Histogram with frequency of admissions by age (in months) in 2016-2017 and 2017-2018

Table 3

Length of Hospital Stay per Admission

ADMT_YEAR			LOS_DAYS	LOS_HRS
2016-2017	N	Valid	***281***	***281***
		Missing	0	0
	Mean		**4.18**	**100.43**
	Median		**2.71**	**65.04**
	Percentiles	25	1.69	40.68
		50	2.71	65.04
		75	4.35	104.28
2017-2018	N	Valid	***320***	***320***
		Missing	0	0
	Mean		**4.93**	**118.25**
	Median		**2.76**	**66.24**
	Percentiles	25	1.68	40.32
		50	2.76	66.24
		75	4.88	117.06

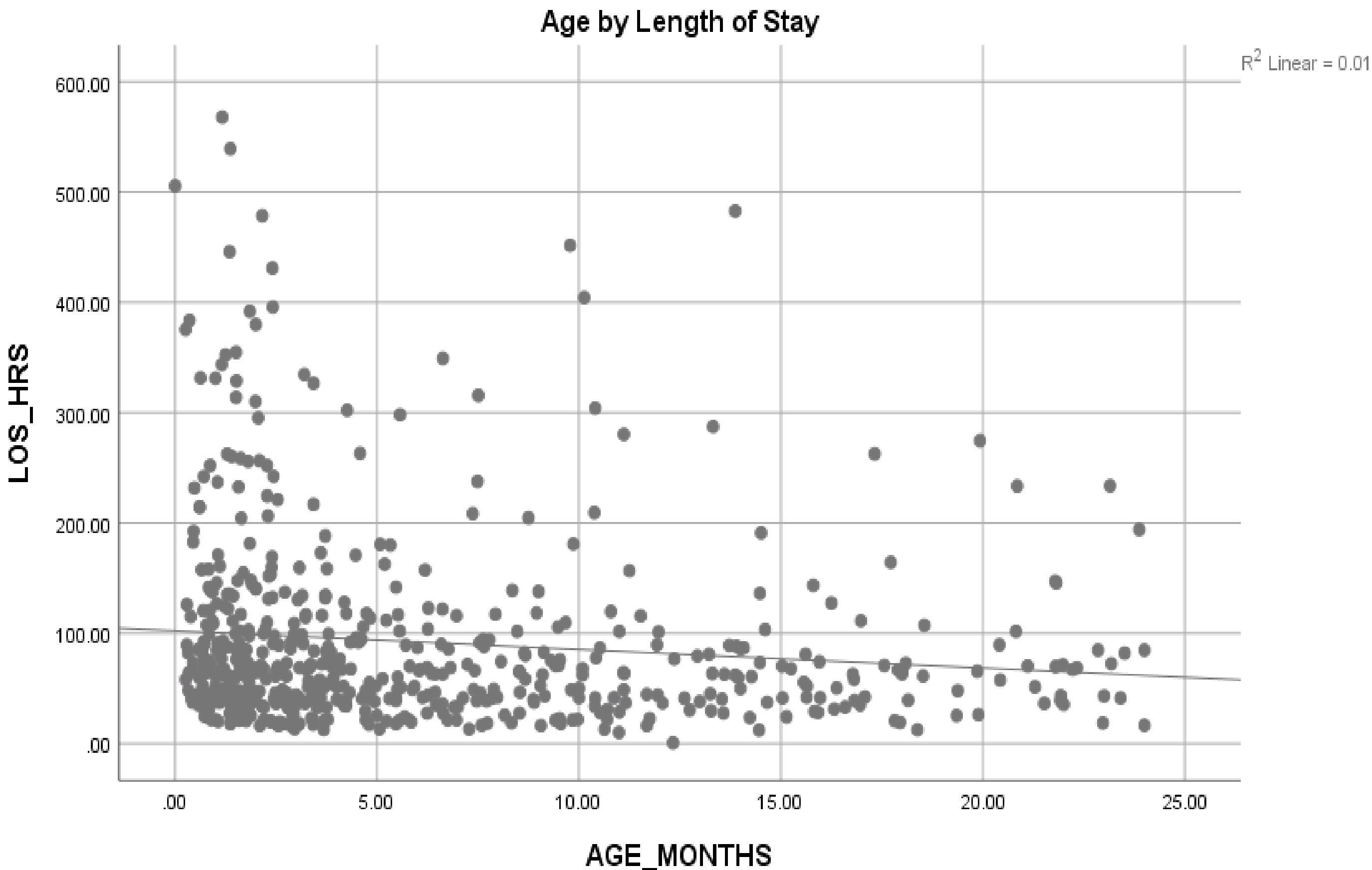
Length of stay (in days and hours) by season

Table 4

Total Cost per Admission and Total Costs				
ADMT_YEAR			TOTAL_DIRECT_COSTS	PICU_DIRECT_COSTS
2016-2017	N	Valid	***281***	***83***
		Missing	0	198
	Mean		**$5,725.62**	**$5,508.35**
	Median		**$2,769.05**	**$2,904.80**
	Std. Deviation		$12,940.66	$7,646.11
	Minimum		$734.72	$0.00
	Maximum		$162,319.58	$39,931.03
	Sum		***$$1.61E+6***	***$457,193.06***
	Percentiles	25	$1,562.10	$1,443.36
		50	$2,769.05	$2,904.80
		75	$5,274.88	$6,599.01
2017-2018	N	Valid	***320***	***85***
		Missing	0	235
	Mean		**$7,053.55**	**$9,892.13**
	Median		**$2,846.66**	**$3,401.92**
	Std. Deviation		$18,500.38	$21,930.50
	Minimum		$678.04	$0.00
	Maximum		$203,595.71	$169,115.76
	Sum		**$$2.26E+6**	**$840,831.03**
	Percentiles	25	$1,633.75	$1,586.30
		50	$2,846.66	$3,401.92
		75	$5,254.20	$8,888.78

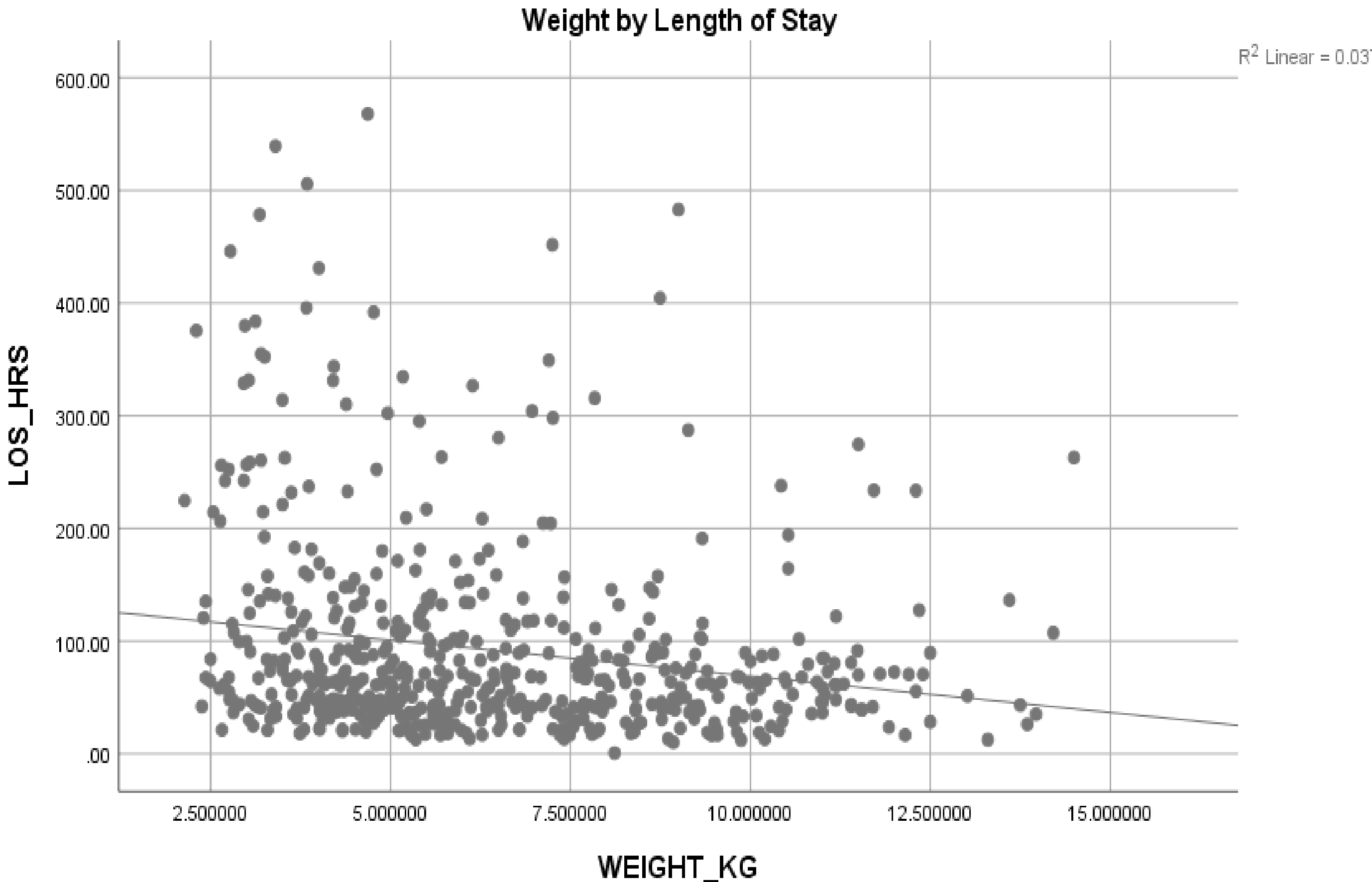
Total direct costs per admission and total. PICU direct costs per admission and total.

Figure 5



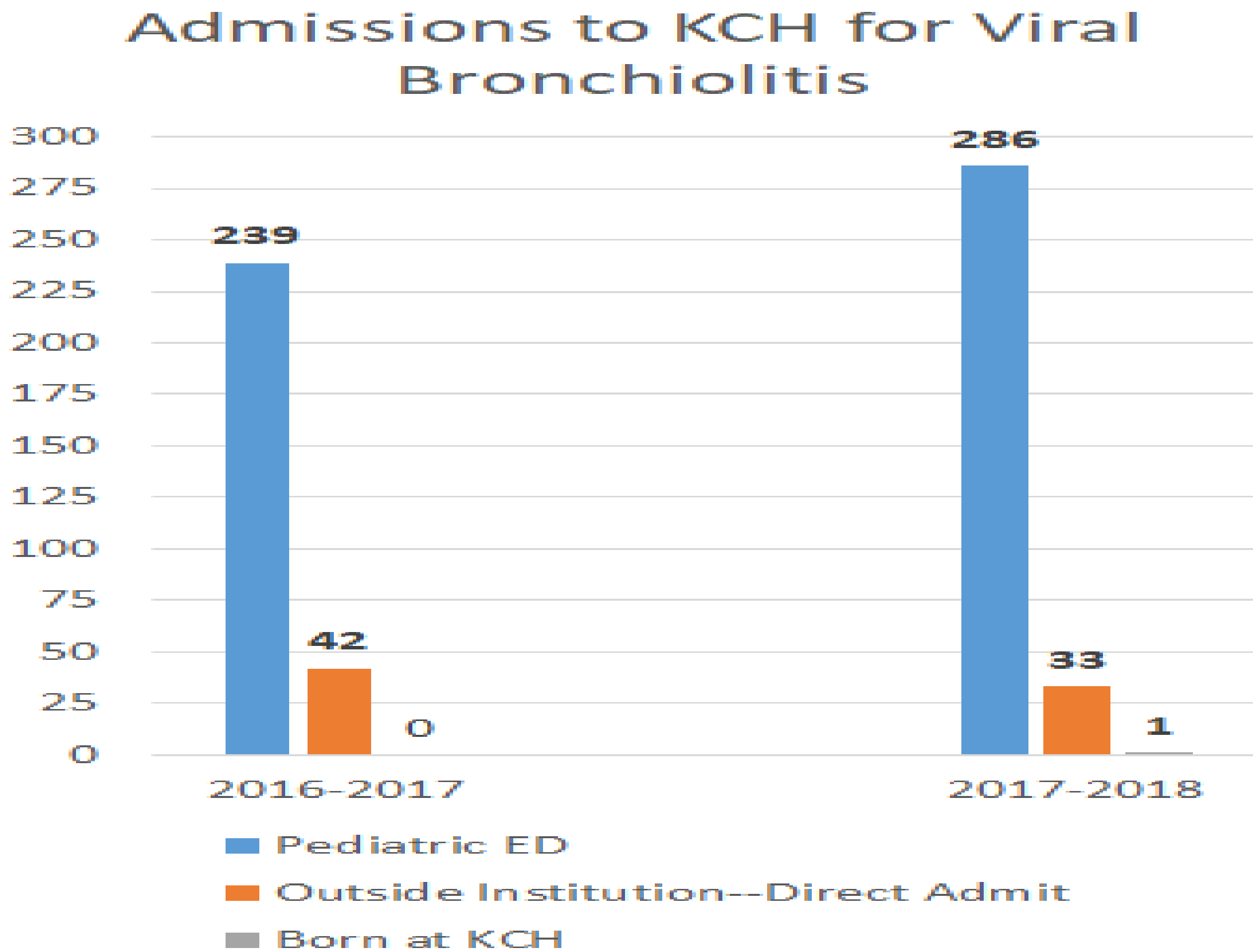
Linear regression of length of stay (in hours) and age (in months). N=589 with outliers >3 standard deviations for length of stay excluded. (r=-0.11, p=0.003)

Figure 6



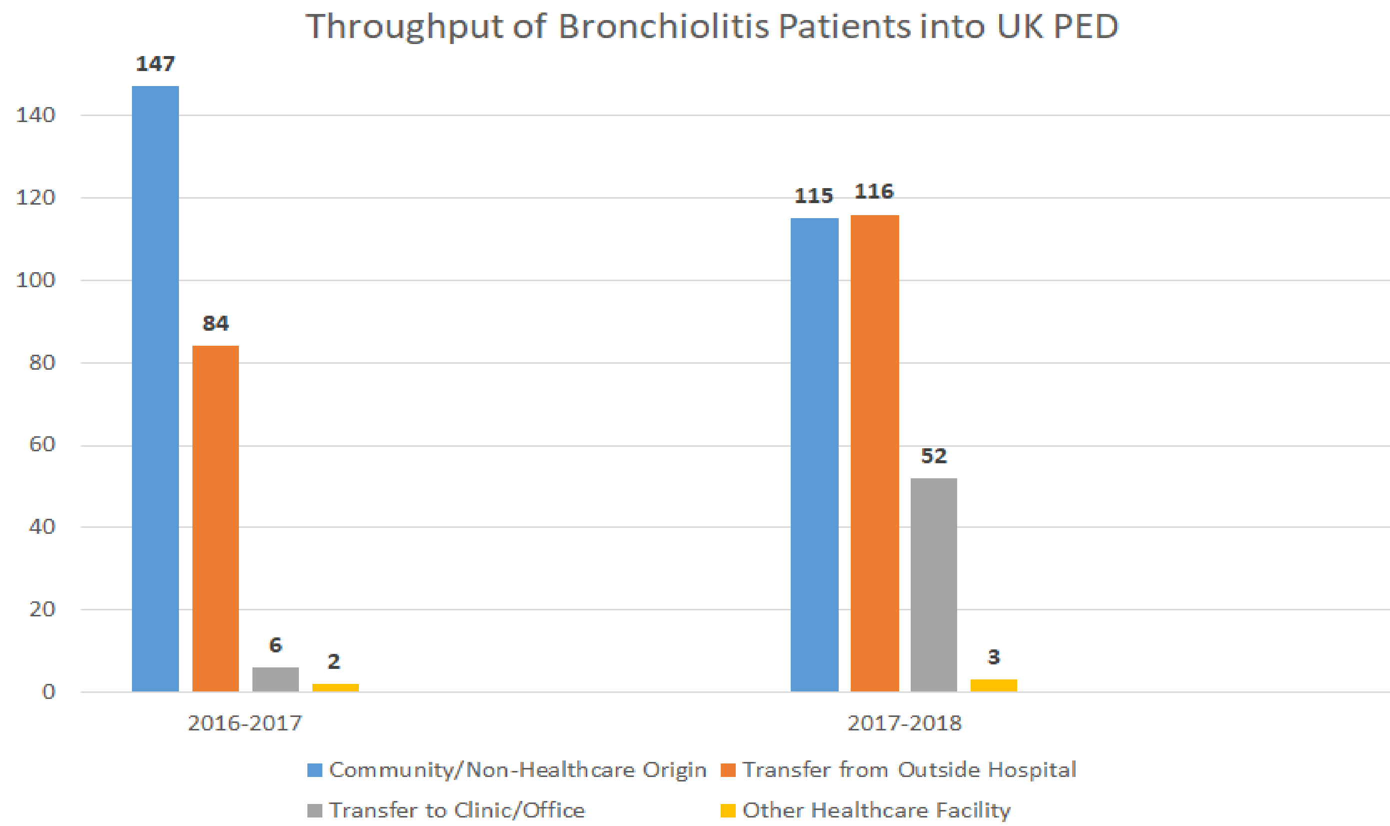
Linear regression of length of stay (in hours) and weight (in Kg). N=589 with outliers >3 standard deviation for length of stay excluded (r=-0.193, p<0.001)

Figure 7



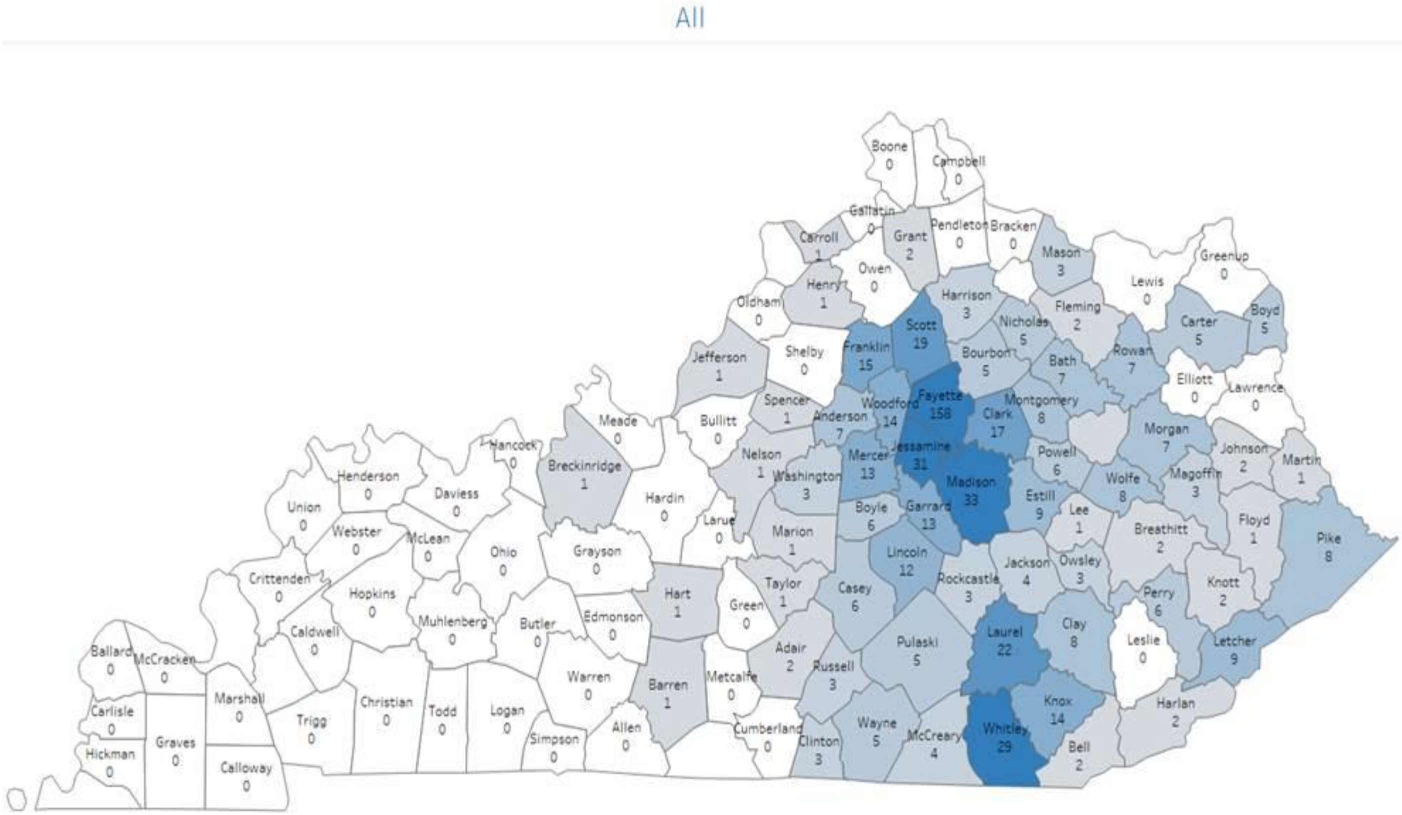
Admissions to KCH for vial bronchiolitis (PED vs outside institution) 2016-17 and 2017-18

Figure 8



Admissions into KCH through the UK PED (2016-17 and 2017-18)

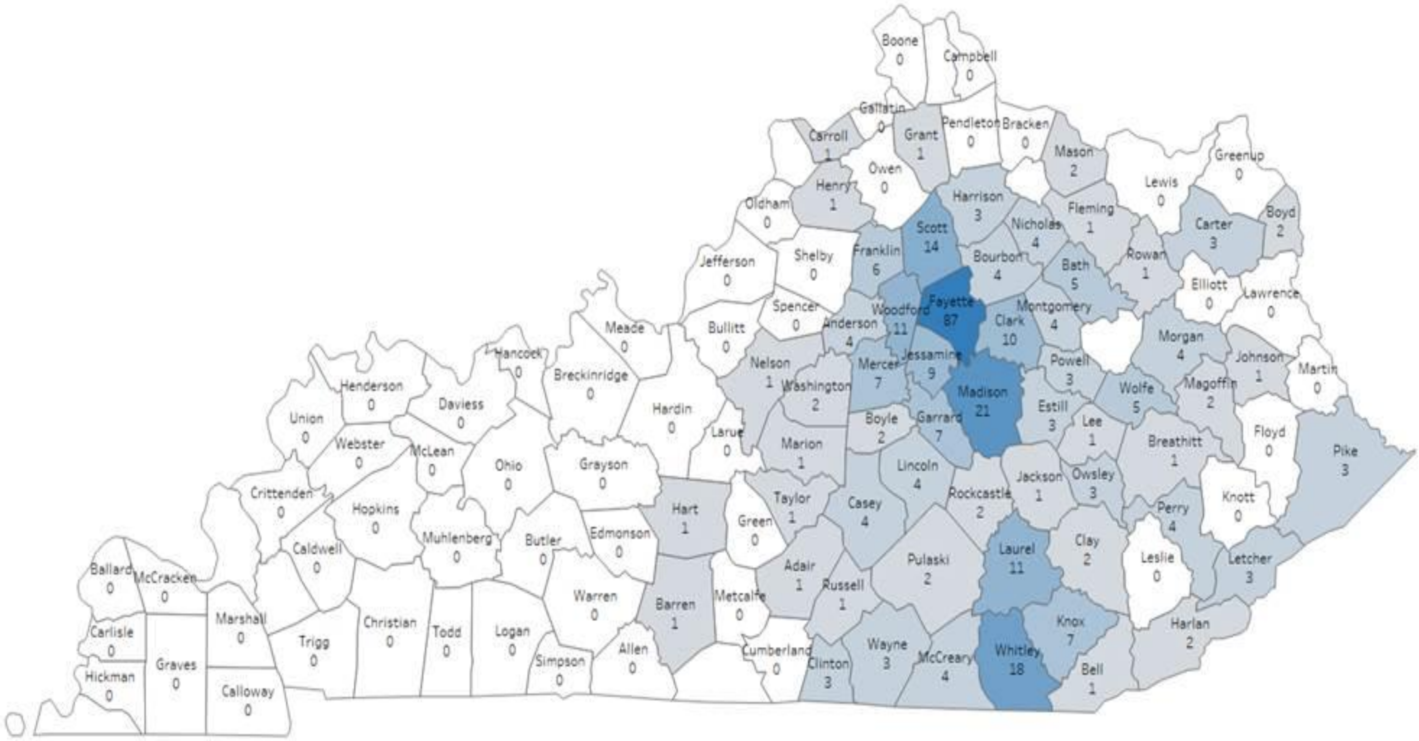
Figure 9



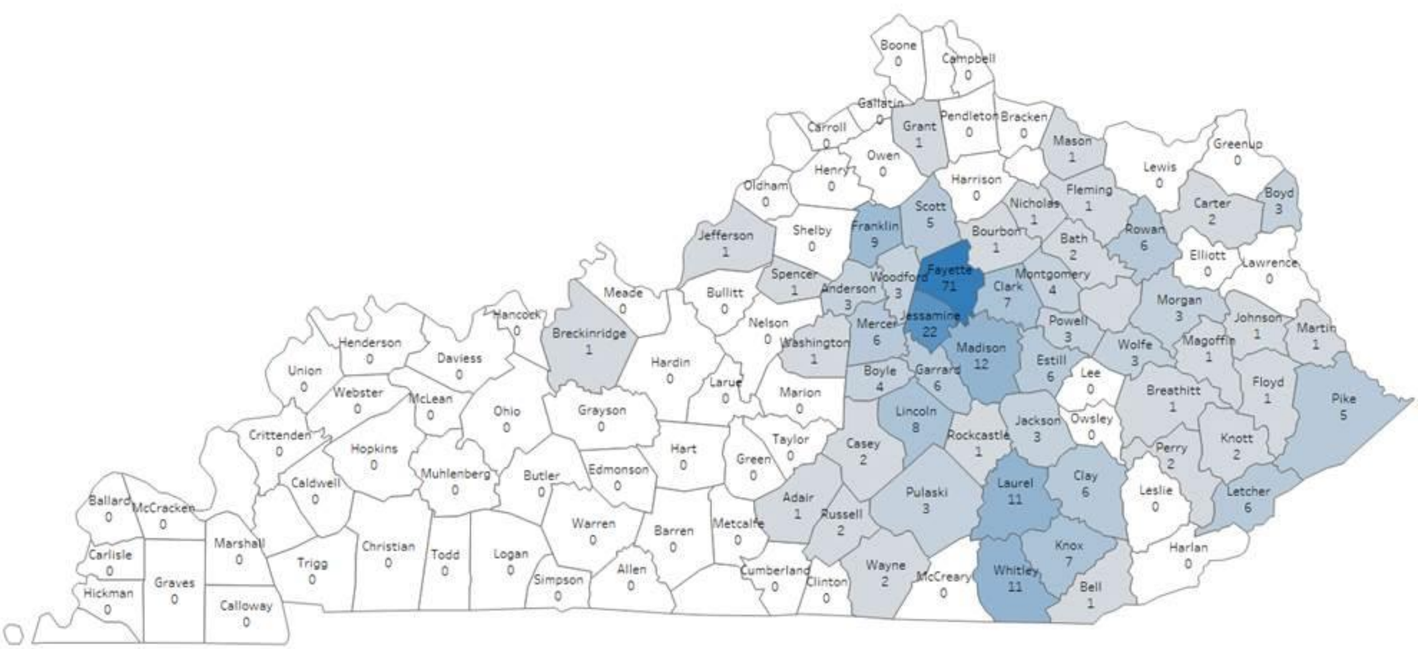
Heat map of admissions by Kentucky County

Figure 10

2017-2018

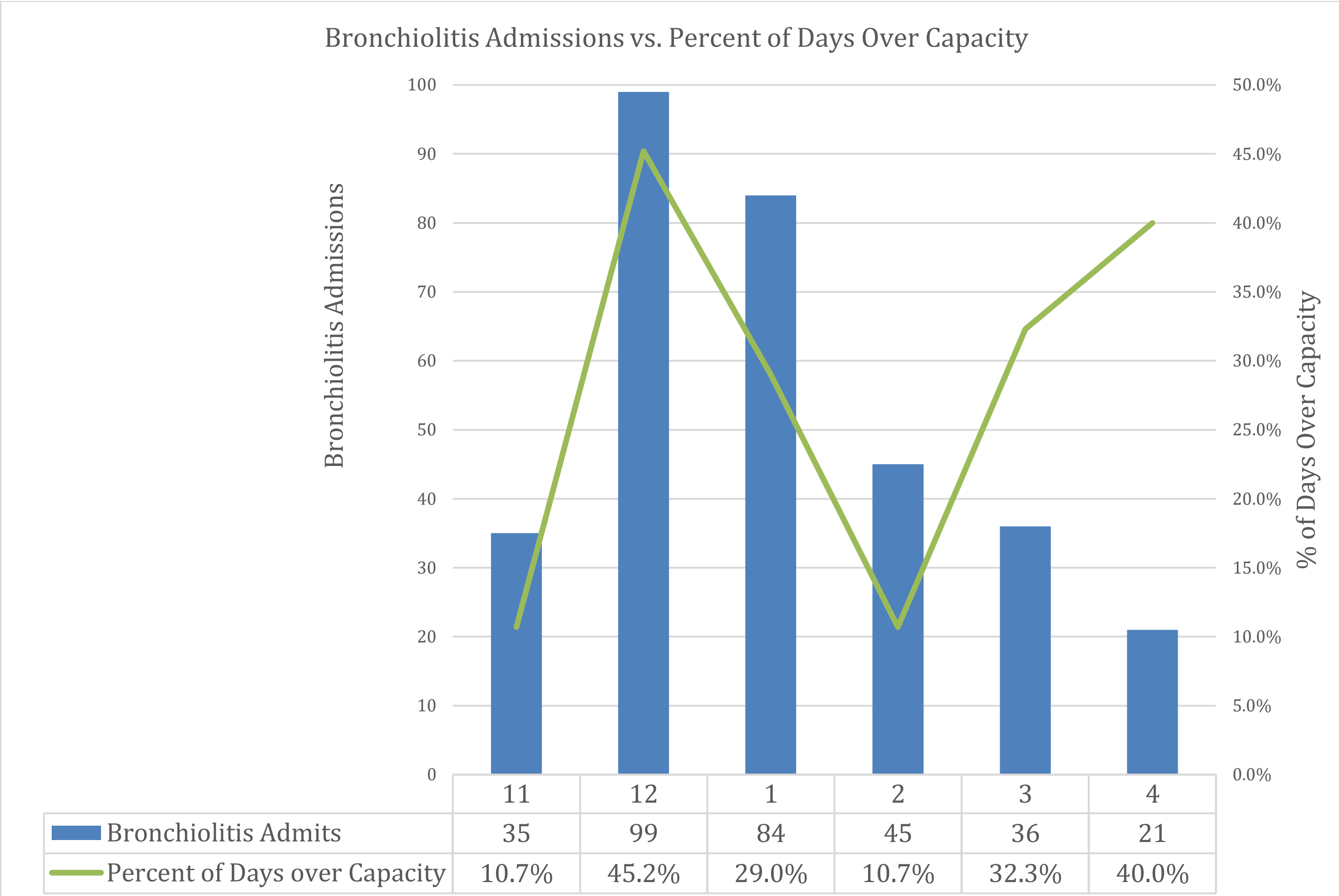


2016-2017



Heat map of Admissions by County by season (2016-17 and 2017-18)

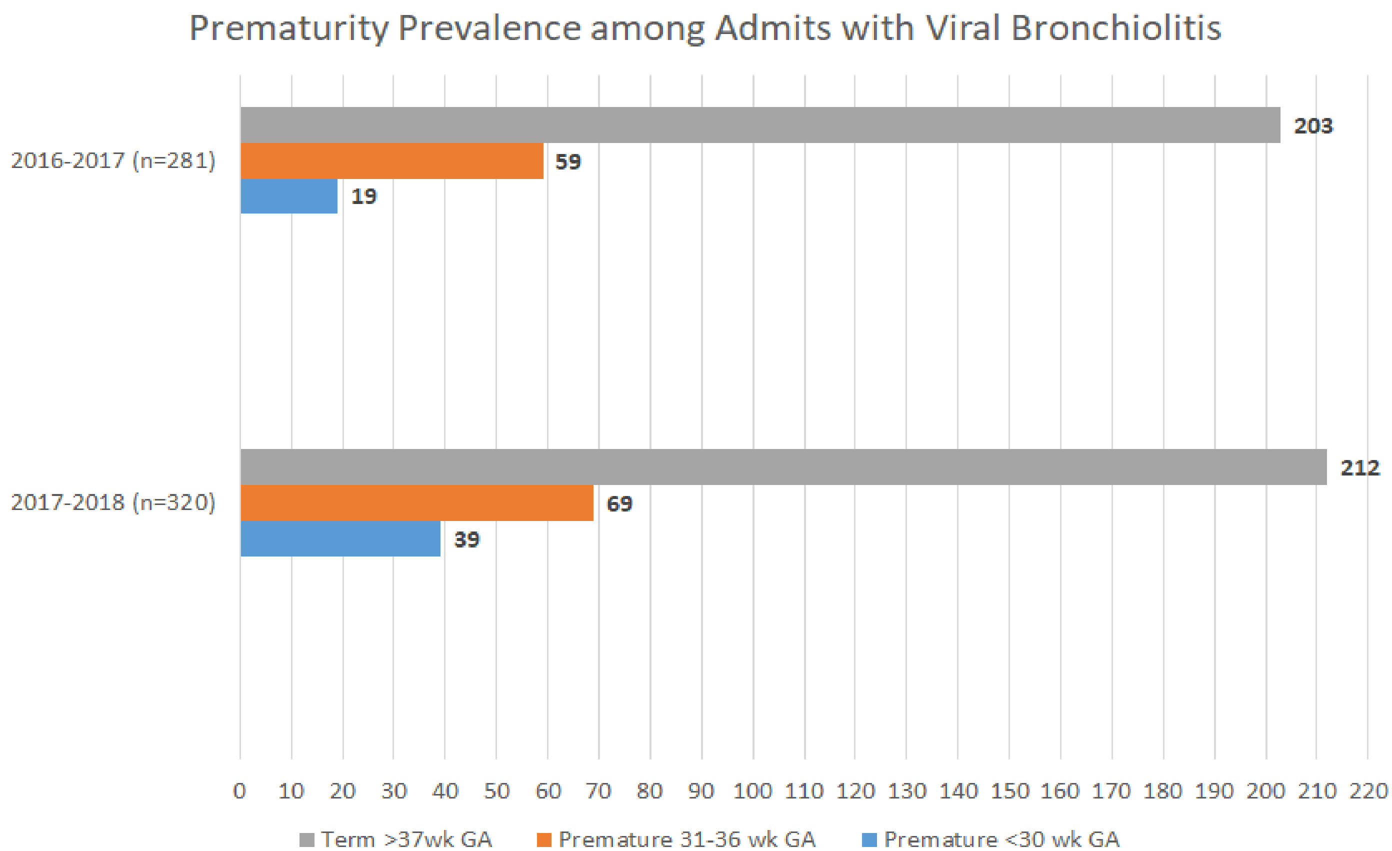
Figure 11



	11	12	1	2	3	4
Bronchiolitis Admits	35	99	84	45	36	21
Percent of Days over Capacity	10.7%	45.2%	29.0%	10.7%	32.3%	40.0%

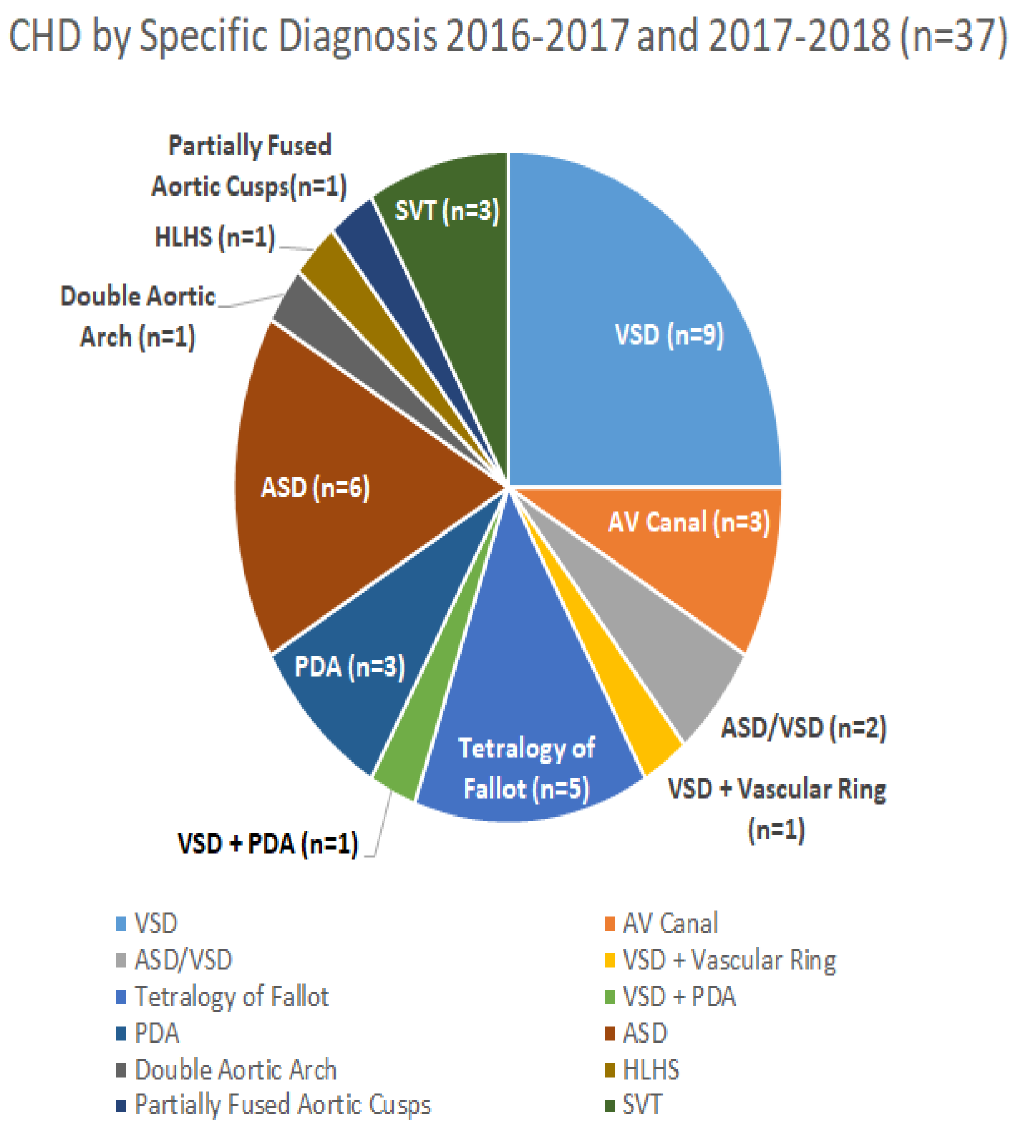
Bronchiolitis admissions by month with percentage of days per month over 100% hospital capacity

Figure 12



Number of Admissions per year by prematurity: Term (≥37 weeks GA), Late term premature (31-36 weeks GA), Severe prematurity (≤30 weeks GA)

Figure 13



Congenital Heart Disease by diagnosis in patients with bronchiolitis

Table 5

Prematurity	+ PICU Admission	- PICU Admission	χ^2
Term (n=415)	101 (24.3%)	314 (75.7%)	
Premature (n=186)	67 (36%)	119 (64%)	$X^2=11.95$ p=0.003

Congenital Heart Disease	+PICU Admission	- PICU Admission	χ^2
No (n=564)	152 (27%)	412 (73%)	
Yes (n=37)	16 (43.2%)	21 (56.8%)	$\chi^2=4.58$ p=0.032

Prematurity and PICU admission

Table 6

Prematurity and Mean LOS in Hours (>3 S.D are filtered out)

LOS_HRS

	N	Mean	Std. Deviation	95% Confidence Interval for Mean	
				Lower Bound	Upper Bound
Term	410	**84.14**	83.16	76.07	92.22
Premature 31-36 weeks	126	**104.86**	95.81	87.96	121.75
Premature 30 weeks or less	53	**121.30**	91.93	95.97	146.64
Total	589	**91.92**	87.55	84.83	99.00

Length of stay by degree of prematurity

Table 7

Prematurity and Total Mean Hospital Costs

		N	Mean	Std. Deviation	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
Total Direct Costs	Term	410	**$4,127.84**	$5,216.92	$3,621.36	$4,634.31
	Premature 31-36 weeks	126	**$5,386.90**	$5,812.46	$4,362.08	$6,411.72
	Premature 30 weeks or less	53	**$5,901.84**	$5,361.03	$4,424.15	$7,379.52
	Total	589	**$4,556.81**	$5,393.87	$4,120.31	$4,993.31
PICU Direct Costs	Term	96	**$4,077.82**	$4,674.54	$3,130.67	$5,024.97
	Premature 31-36 weeks	39	**$6,172.87**	$5,181.31	$4,493.28	$7,852.45
	Premature 30 weeks or less	21	**$4,362.41**	$5,378.64	$1,914.08	$6,810.74
	Total	156	**$4,639.89**	$4,950.21	$3,856.98	$5,422.80

Total Hospital Costs and PICU direct costs by degree of prematurity

Figure 14

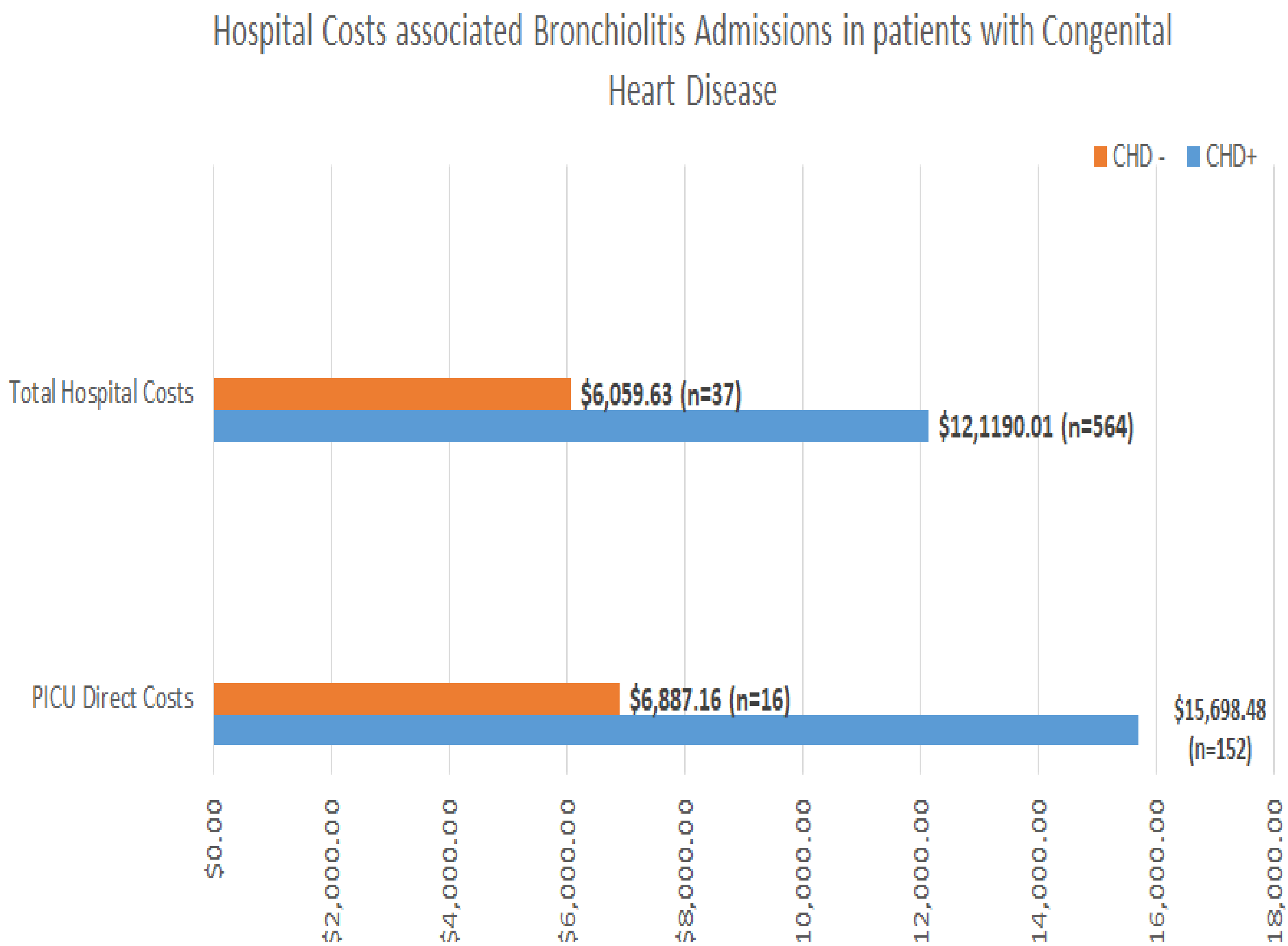
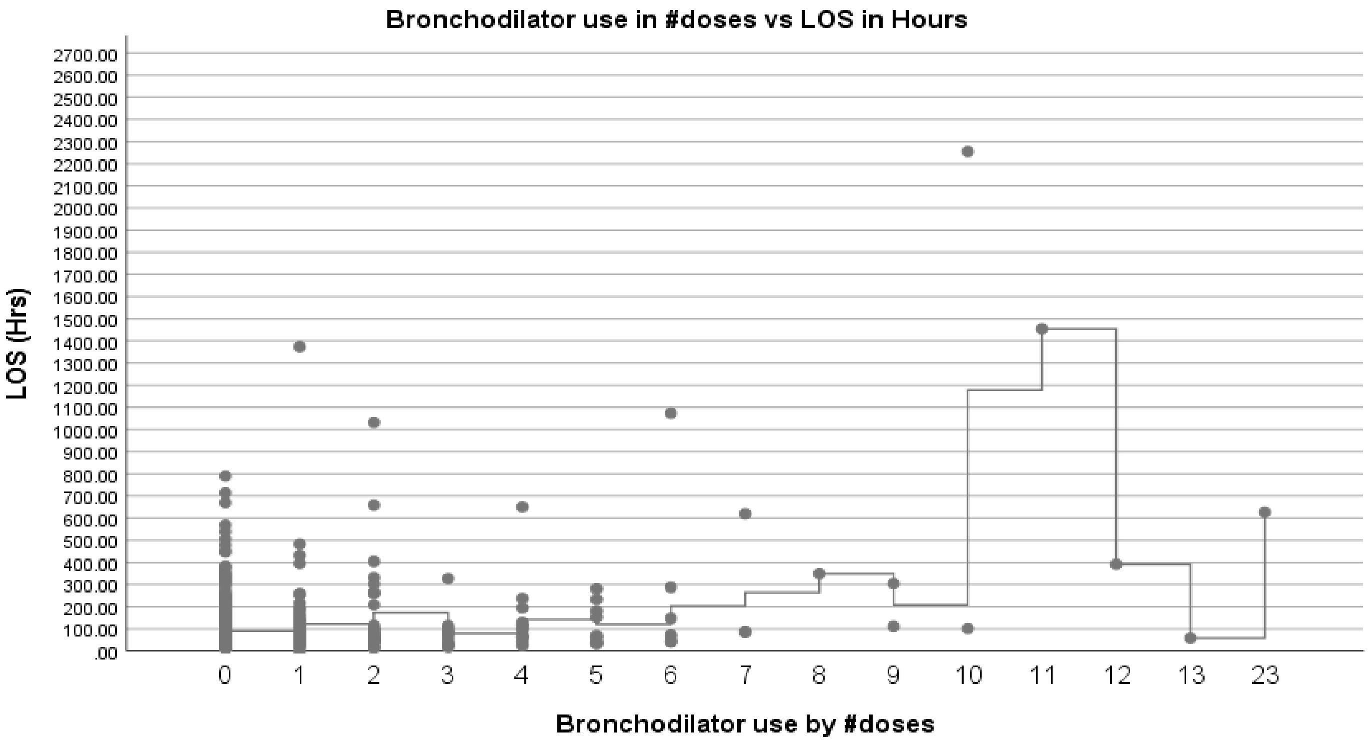

Hospital Costs associated Bronchiolitis Admissions in patients with Congenital Heart Disease
CHD -
CHD+
Total Hospital Costs
$6,059.63 (n=37)
$12,1190.01 (n=564)
PICU Direct Costs
$6,887.16 (n=16)
$15,698.48 (n=152)
$0.00
$2,000.00
$4,000.00
$6,000.00
$8,000.00
10,000.00
12,000.00
14,000.00
16,000.00
18,000.00

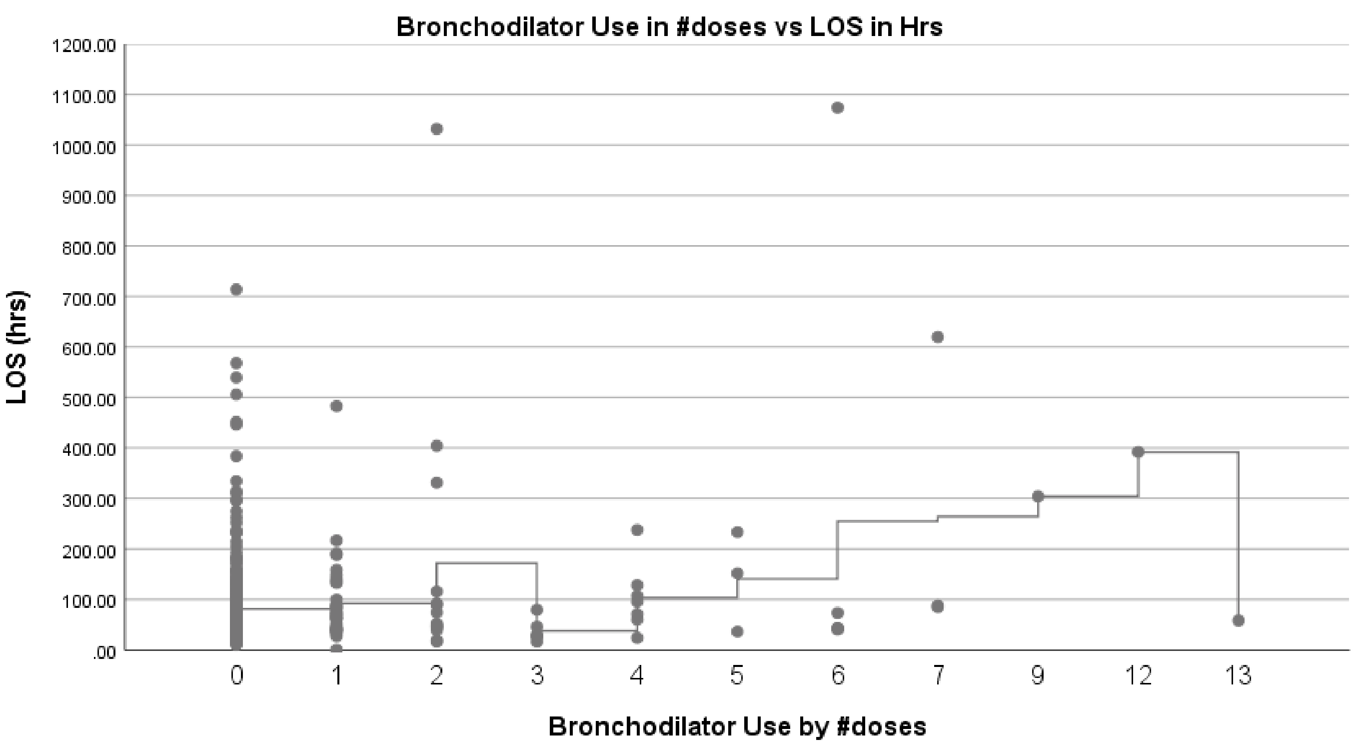
Table 8

LOS (Hrs) in Patients with CHD

	Congenital Heart Disease	N	Mean	Std. Deviation
LOS in HRS	Yes	37	161.62	247.85
	No	564	106.52	160.08

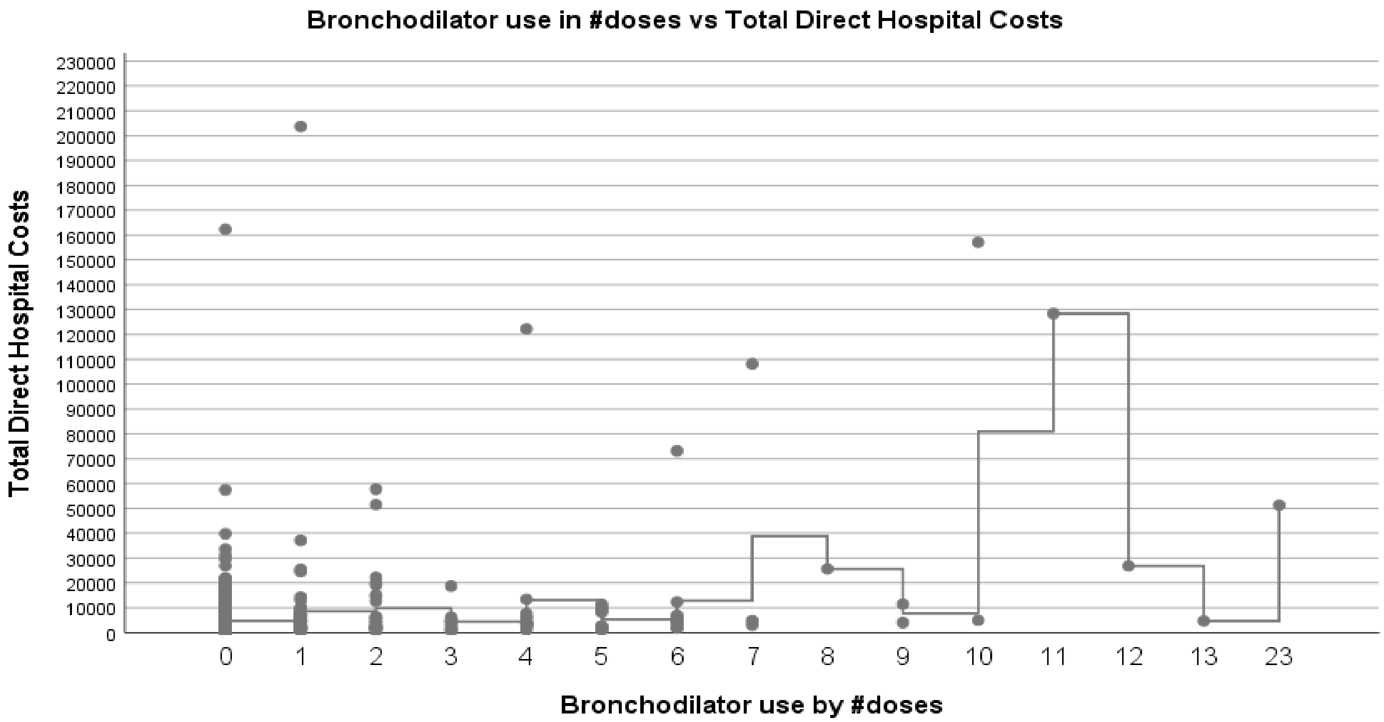
Figure 15

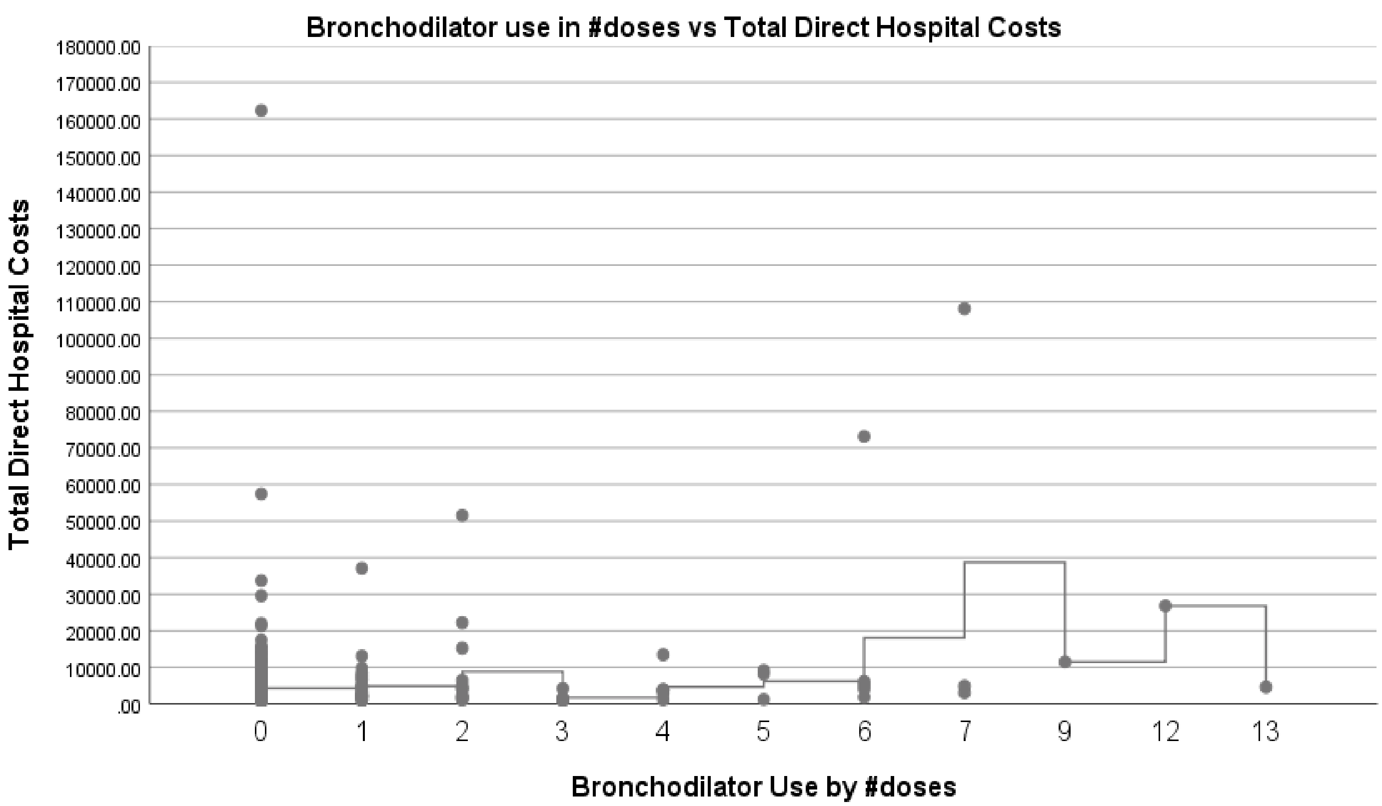




Optimal Care Candidates Only

Figure 15 (continued)





Optimal Care Candidates only n=78

Table 9

2016-2017	Optimal Care Candidate	Not Optimal Care Candidate	χ^2
No Bronchodilator Use	154 (79.8%)	62	
+ Bronchodilator Use	39 (20.2%)	26 (29.5%)	
	193	88	X^2=2.964 ***p=.085***
2017-2018	**Optimal Care Candidate**	**Not Optimal Care Candidate**	**χ^2**
No Bronchodilator Use	160 (80.4%)	77	
+Bronchodilator Use	39 (19.6%)	44 (33.5%)	
	199	121	X^2=11.010 ***p=.001***
Overall Utilization	78/392 (19.9%)	70/209 (33.5%)	X^2=13.574 ***p<.001***

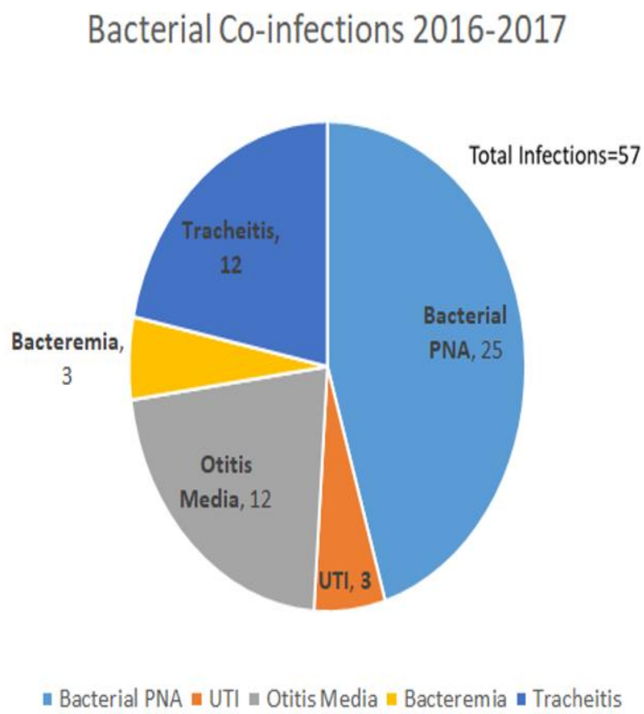
Optimal Care candidates and bronchodilator use

Table 10

2016-2017	Optimal Care Candidate	Not Optimal Care Candidate	χ^2
No Steroids	153 (79.3%)	65	
+ Steroids	40 (20.7%)	23 (26.1%)	
	193	88	X^2=1.017 **p=.313**
2017-2018	**Optimal Care Candidate**	**Not Optimal Care Candidate**	
No Steroids	173 (86.9%)	81	
+ Steroids	26 (13.1%)	40 (33.1%)	
	199	121	X^2=18.372 **p<.001**
	66/392 (16.8%)	63/209 (30.1%)	X^2=14.319 **p<.001**

Optimal Care Candidates and systemic corticosteroid use

Figure 16


Bacterial Co-infections 2016-2017
Total Infections=57
Tracheitis, 12
Bacterial PNA, 25
Bacteremia, 3
Otitis Media, 12
UTI, 3
Bacterial PNA
UTI
Otitis Media
Bacteremia
Tracheitis

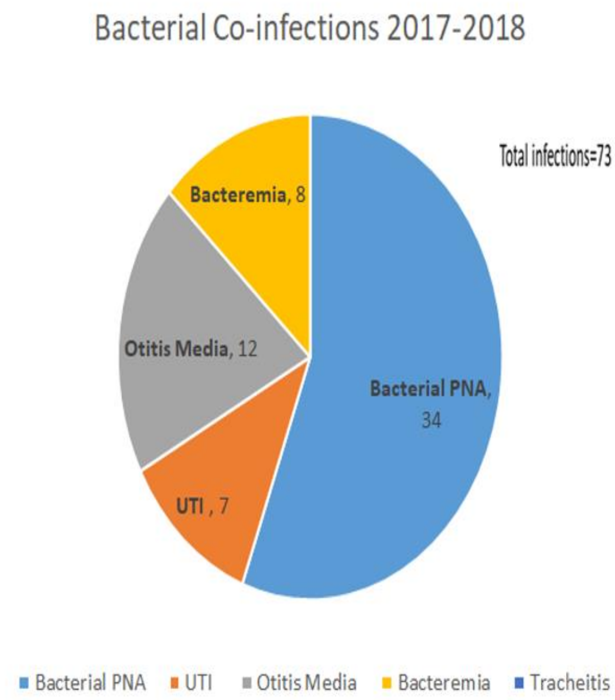

Bacterial Co-infections 2017-2018
Total infections=73
Bacteremia, 8
Otitis Media, 12
Bacterial PNA, 34
UTI, 7
Bacterial PNA
UTI
Otitis Media
Bacteremia
Tracheitis

Table 11

2016-2017	Optimal Care	Not Optimal Care	χ^2
No Antibiotics	126 (74.6%)	55	
+ Antibiotics	43 (25.4%)	17 (23.6%)	
	169	72	X^2=.091 ***p=.763***
2017-2018	**Optimal Care**	**Not Optimal Care**	χ^2
No Antibiotics	133 (81.6%)	78	
+ Antibiotics	30 (18.4%)	21 (21.2%)	
	163	99	X^2=.310 ***p=.578***
	73/332 (21.9%)	38/171 (22.2%)	X^2=.004 ***p=.952***

Optimal Care Candidates and antibiotic use

Figure 17

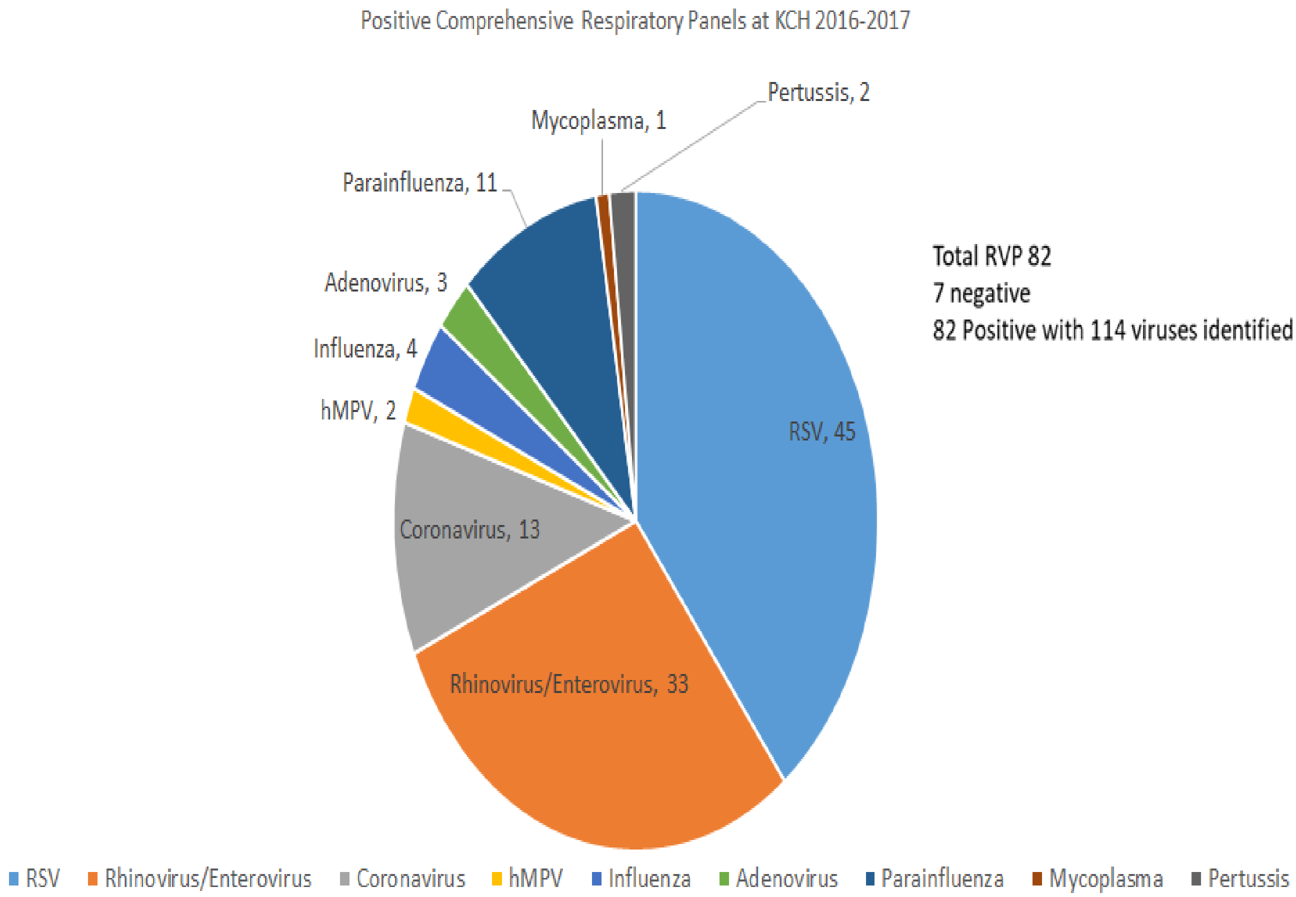

Positive Comprehensive Respiratory Panels at KCH 2016-2017
Pertussis, 2
Mycoplasma, 1
Parainfluenza, 11
Adenovirus, 3
Influenza, 4
hMPV, 2
Coronavirus, 13
Rhinovirus/Enterovirus, 33
RSV, 45
Total RVP 82
7 negative
82 Positive with 114 viruses identified
RSV
Rhinovirus/Enterovirus
Coronavirus
hMPV
Influenza
Adenovirus
Parainfluenza
Mycoplasma
Pertussis

Figure 18

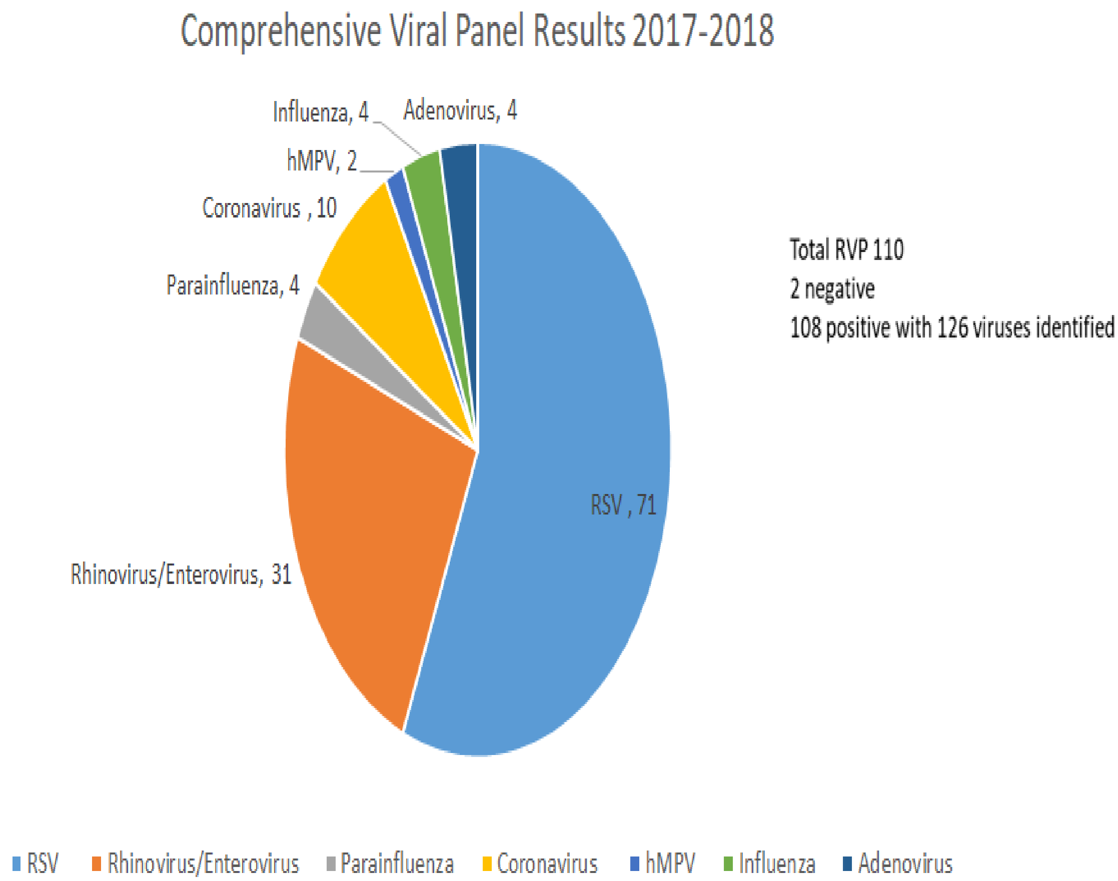

Comprehensive Viral Panel Results 2017-2018
Influenza, 4
Adenovirus, 4
hMPV, 2
Coronavirus , 10
Parainfluenza, 4
Rhinovirus/Enterovirus, 31
RSV , 71
Total RVP 110
2 negative
108 positive with 126 viruses identified
RSV
Rhinovirus/Enterovirus
Parainfluenza
Coronavirus
hMPV
Influenza
Adenovirus

Table 12

2016-2017	Optimal Care Candidate	Not Optimal Care Candidate	X^2
No chest radiograph	103 (53.4%)	41	
+ chest radiograph	90 (46.6%)	47 (53.4%)	
Total	193	88	X^2=1.111 **p=.292**
2017-2018	**Optimal Care Candidate**	**Not Optimal Care Candidate**	
No Chest radiograph	110 (55.3%)	48 (39.7%)	
+ chest radiograph	89 (44.7%)	73 (60.3%)	
	199	121	X^2=7.333 **p=.007**
	179/392 (45.7%)	120/209 (57.4%)	X^2=7.532 **p=.006**

Optimal Care candidates and radiograph use

Table 13

2016-2017	Optimal Care Candidate	Not Optimal Care Candidate	χ^2
+Respiratory Panel Testing	**57 (29.5%)**	32 (36.4%)	
No Respiratory Panel Testing	136 (70.5%)	56 (63.6)	
Total	193	88	χ2=1.303 **p=.254**

2017-2018	Optimal Care Candidate	Not Optimal Care Candidate	χ^2
+Respiratory Panel Testing	**57 (28.6%)**	53 (43.8%)	
No Respiratory Panel Testing	142 (71.4%)	68 (56.2%)	
Total	199	121	χ^2=7.665 **p=.006**
	114/392 (29.1%)	85/209 (40.7%)	X^2=8.265 **p=.004**

Optimal care candidates and respiratory panel testing

Table 14

PICU Admission During Hospitalization

Admit Season		n	Percent
2016-2017	NO	198	70.5
	YES	**83**	**29.5**
	Total	281	100.0
2017-2018	NO	235	73.4
	YES	**85**	**26.6**
	Total	320	100.0

Initial Admission to PICU

Admit Year		Frequency	Percent
2016-2017	NO	232	82.6
	YES	**49**	**17.4**
	Total	281	100.0
2017-2018	NO	268	83.8
	YES	**52**	**16.3**
	Total	320	100.0

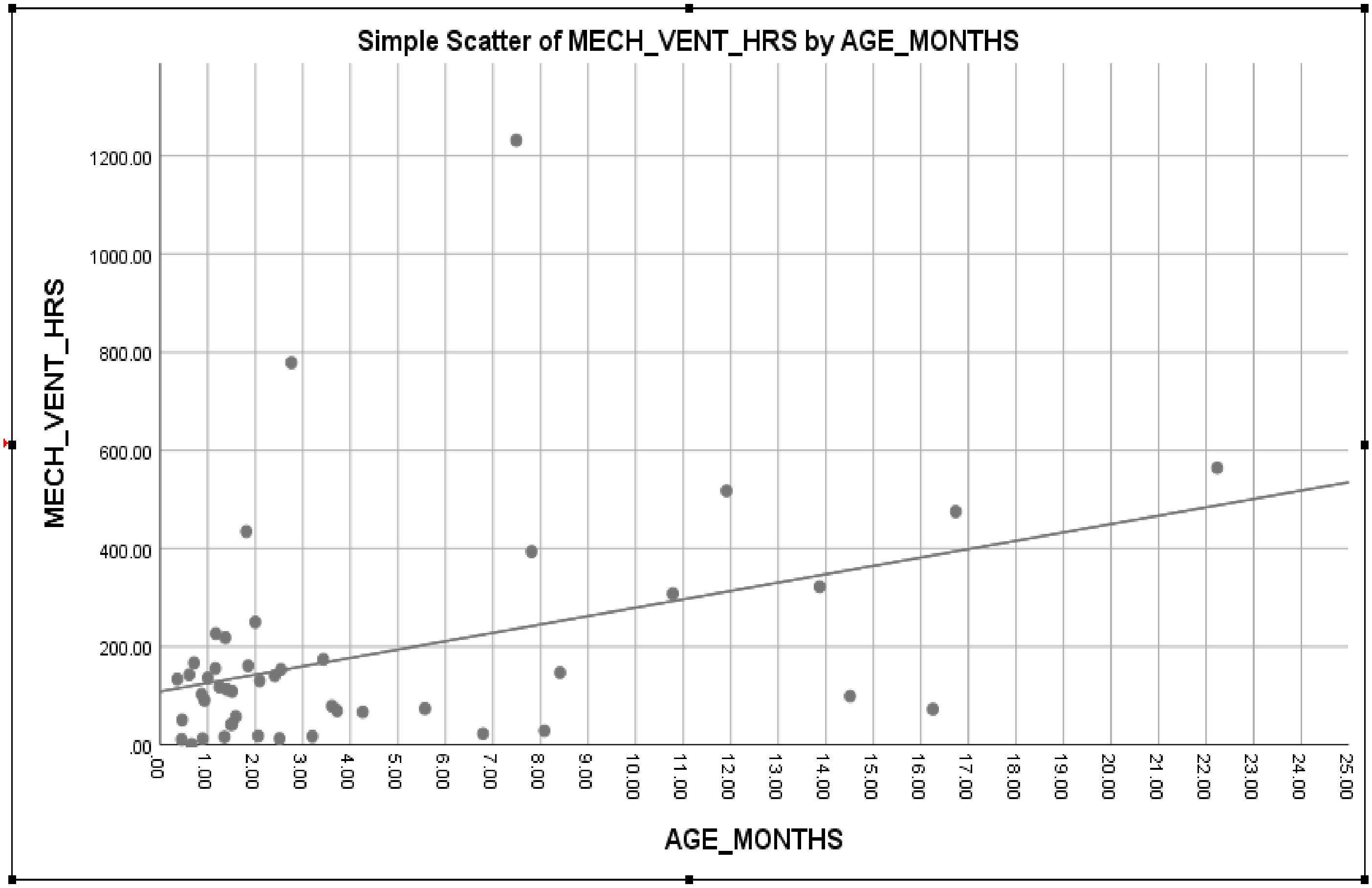
Table 15

Prematurity	+ PICU Admission	- PICU Admission	χ^2
Term (n=415)	101 (24.3%)	314 (75.7%)	
Premature (n=186)	67 (36%)	119 (64%)	$X^2=11.95$ p=0.003

Congenital Heart Disease	+PICU Admission	- PICU Admission	χ^2
No (n=564)	152 (27%)	412 (73%)	
Yes (n=37)	16 (43.2%)	21 (56.8%)	$\chi^2=4.58$ p=0.032

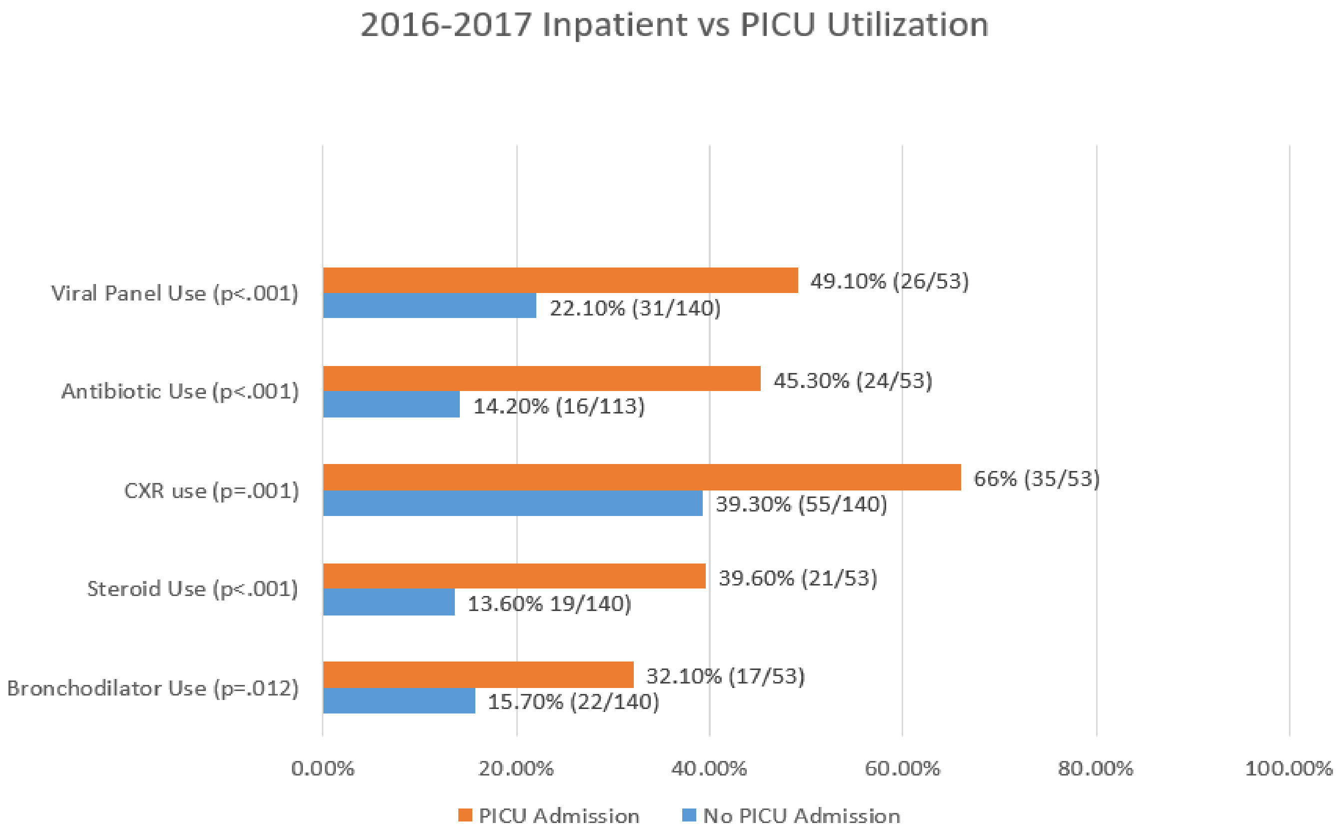
Prematurity and congenital heart disease and PICU admission

Figure 19



Linear regression of hours on mechanical ventilation and age (in months) (r=.388, p=.007)

Figure 20


2016-2017 Inpatient vs PICU Utilization
Viral Panel Use (p<.001)
49.10% (26/53)
22.10% (31/140)
Antibiotic Use (p<.001)
45.30% (24/53)
14.20% (16/113)
CXR use (p=.001)
66% (35/53)
39.30% (55/140)
Steroid Use (p<.001)
39.60% (21/53)
13.60% 19/140)
Bronchodilator Use (p=.012)
32.10% (17/53)
15.70% (22/140)
0.00%
20.00%
40.00%
60.00%
80.00%
100.00%
PICU Admission
No PICU Admission

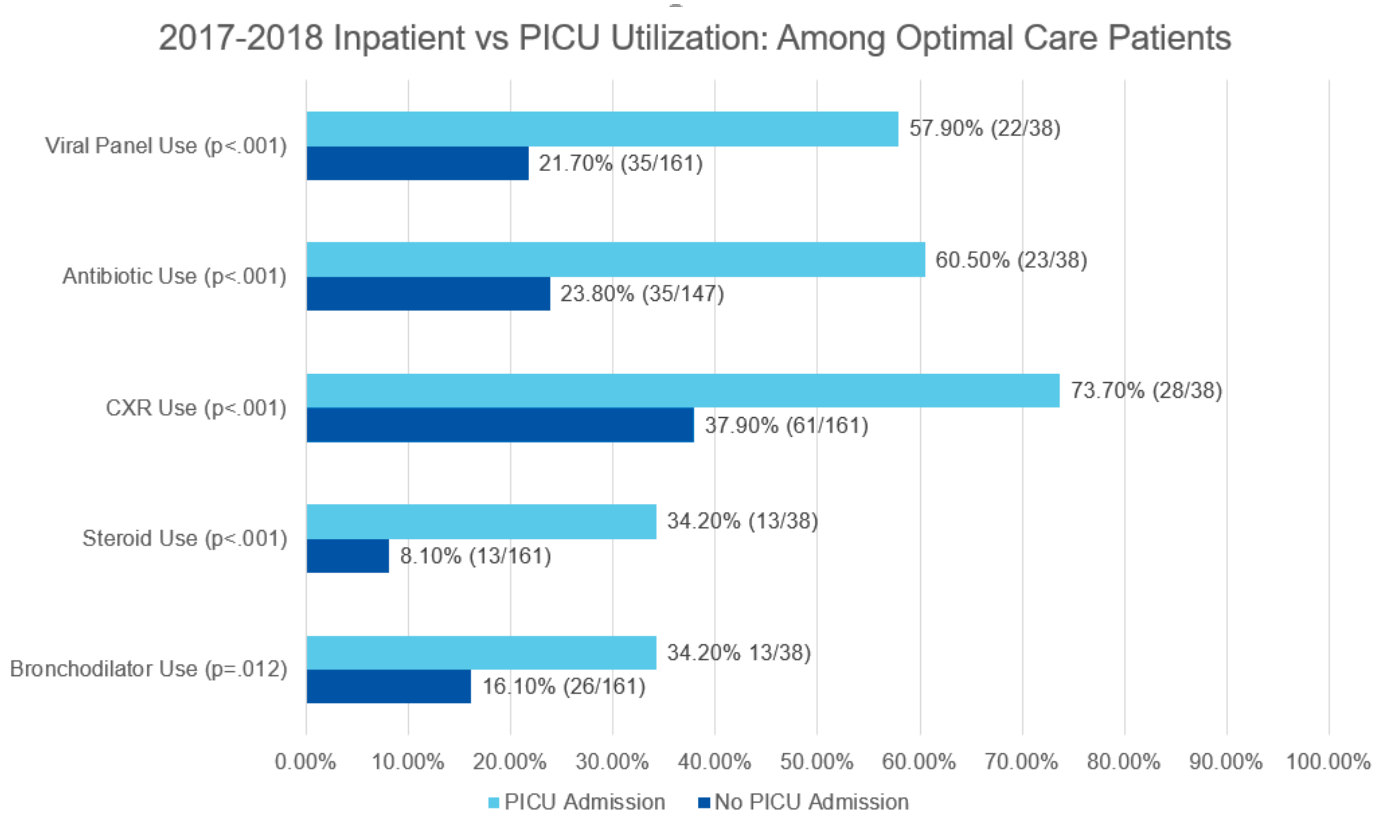

2017-2018 Inpatient vs PICU Utilization: Among Optimal Care Patients
Viral Panel Use (p<.001)
57.90% (22/38)
21.70% (35/161)
Antibiotic Use (p<.001)
60.50% (23/38)
23.80% (35/147)
CXR Use (p<.001)
73.70% (28/38)
37.90% (61/161)
Steroid Use (p<.001)
34.20% (13/38)
8.10% (13/161)
Bronchodilator Use (p=.012)
34.20% 13/38)
16.10% (26/161)
0.00%
10.00%
20.00%
30.00%
40.00%
50.00%
60.00%
70.00%
80.00%
90.00%
100.00%
PICU Admission
No PICU Admission

Figure 21

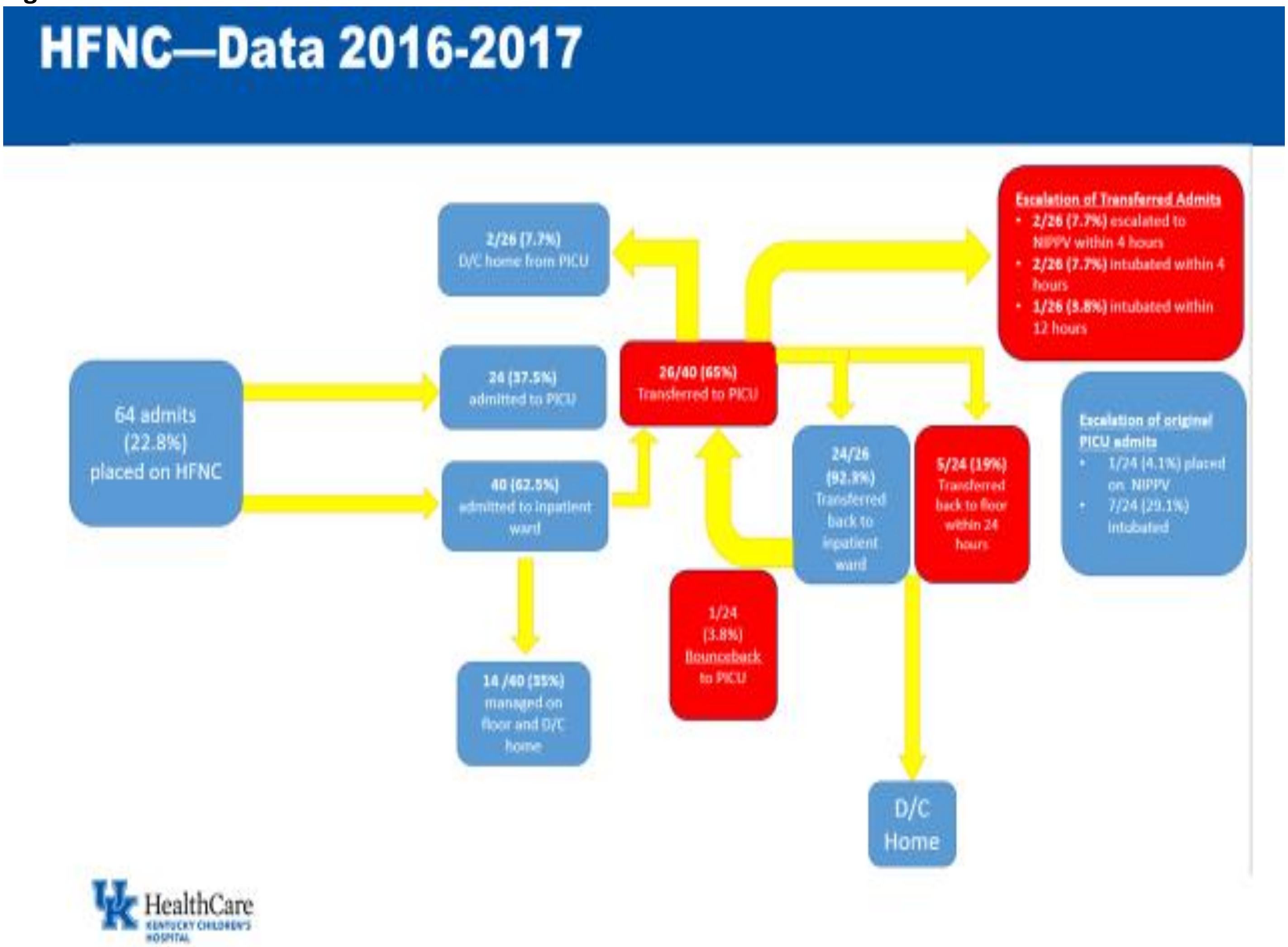

HFNC—Data 2016-2017
64 admits (22.8%) placed on HFNC
24 (37.5%) admitted to PICU
40 (62.5%) admitted to inpatient ward
2/26 (7.7%) D/C home from PICU
26/40 (65%) Transferred to PICU
14 /40 (35%) managed on floor and D/C home
1/24 (3.8%) Bounceback to PICU
24/26 (92.3%) Transferred back to inpatient ward
5/24 (19%) Transferred back to floor within 24 hours
D/C Home
Escalation of Transferred Admits
2/26 (7.7%) escalated to NIPPV within 4 hours
2/26 (7.7%) intubated within 4 hours
1/26 (3.8%) intubated within 12 hours
Escalation of original PICU admits
1/24 (4.1%) placed on NIPPV
7/24 (29.1%) intubated
HealthCare
KENTUCKY CHILDREN'S HOSPITAL

Figure 21 (continued)

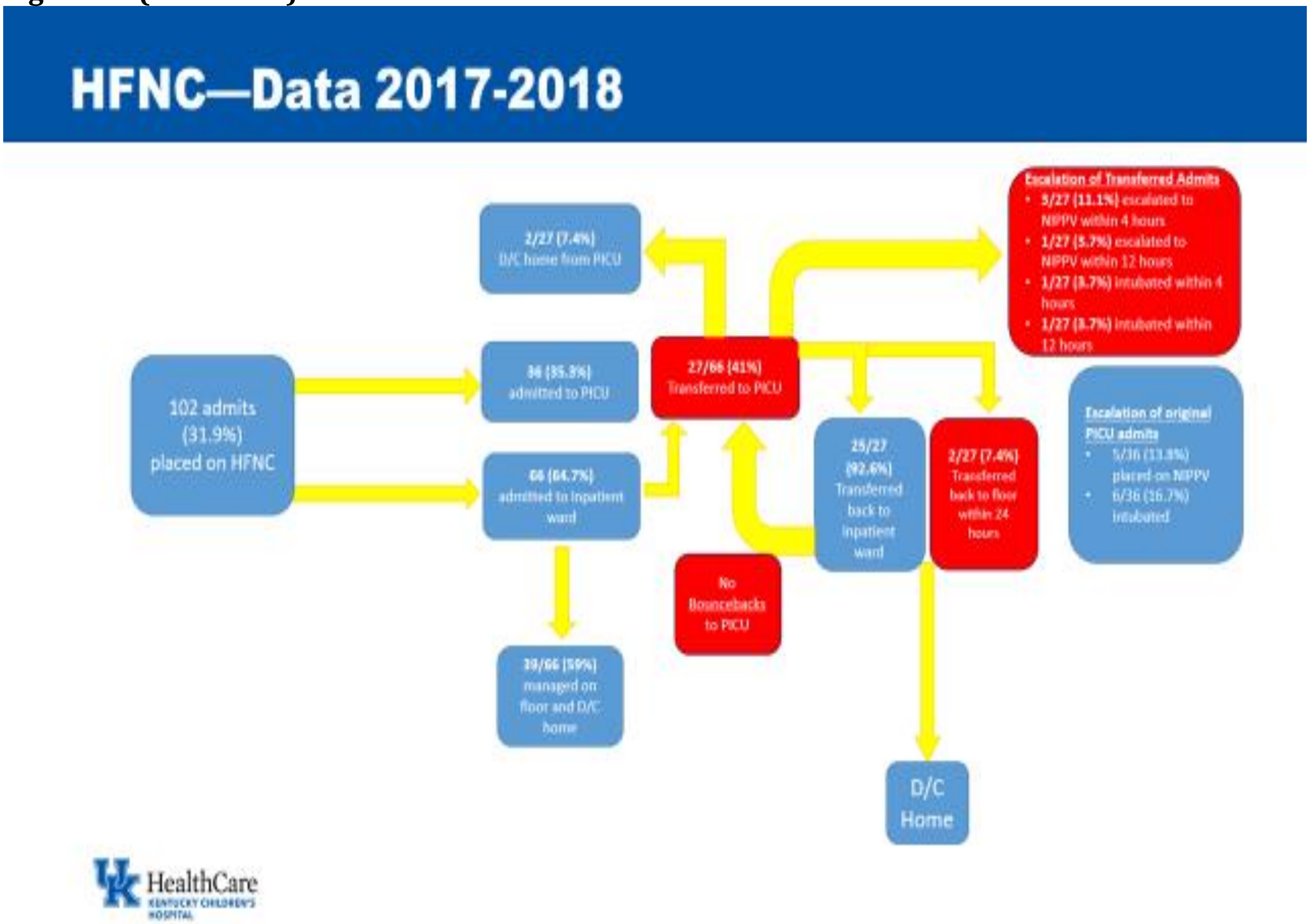


Table 16

PICU vs Ward HFNC Metrics

Year	Started in PICU		LOS in Hrs	PICU LOS	Total Hospital Costs	PICU Costs
2016-2017	NO (n=40)	Mean	**158.44**	**106.95**	**10878.99**	**5929.81**
	YES (n=24)	Mean	**174.75**	**95.21**	**10183.84**	**5397.58**
	Total	Mean	164.55	101.31	10618.31	5674.34
		Ind. t-test	p=0.598	p=0.692	p=0.895	p=.770
2017-2018	NO (n=40)	Mean	**193.57**	**175.49**	**10312.77**	**8911.73**
	YES (n=24)	Mean	**255.45**	**172.32**	**21710.57**	**13030.25**
	Total	Mean	215.41	173.68	14335.52	11265.17
		Ind. t-test	p=0.342	p=0.967	p=0.147	p=0.522

Length of stay on ward vs PICU and total hospital costs + PICU costs for patients on HFNC

Figure 22

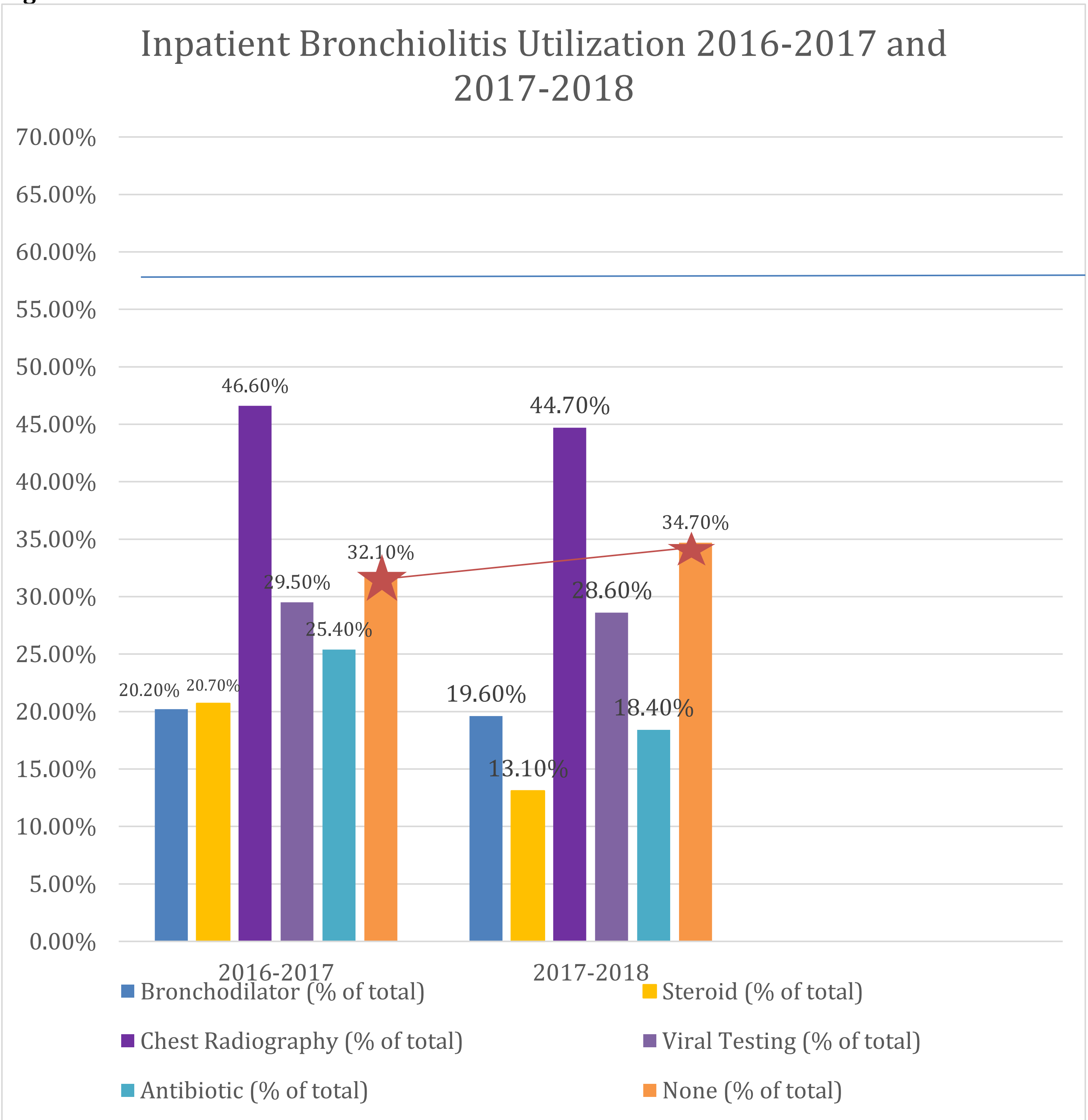

Inpatient Bronchiolitis Utilization 2016-2017 and 2017-2018
70.00%
65.00%
60.00%
55.00%
50.00%
45.00%
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
46.60%
44.70%
34.70%
32.10%
29.50%
28.60%
25.40%
20.20%
20.70%
19.60%
18.40%
13.10%
2016-2017
2017-2018
Bronchodilator (% of total)
Steroid (% of total)
Chest Radiography (% of total)
Viral Testing (% of total)
Antibiotic (% of total)
None (% of total)

Figure 23

	KCH 2016-2017	KCH 2017-2018	
Optimal Care Candidates	193	199	
Bronchodilator	39 (20.2%)	39 (19.6%)	
Steroid	40 (20.7%)	26 (13.1%)	
Antibiotics	43 (25.4%)	30 (18.4%)	
Viral Testing	57 (29.5%)	57 (28.6%)	
Radiograph	90 (46.6%)	89 (44.7%)	
None	62 (32.1%)	69 (34.7%)	
HFNC Transfers to PICU	26/40 (65%)	27/66 (41%)	
Escalation of PICU transfers HFNC→NIPPV (w/in 12 hours)	2/26 (7.7%)	4/27 (14.8%)	
Escalation of PICU Admits HFNC→NIPPV	1/24 (4.1%)	5/36 (13.8%)	
Escalation of PICU transfers HFNC→ Intubation (w/in 12 hours)	3/26 (11.5%)	2/27 (7.4%)	
Escalation of PICU Admits HFNC→ Intubation	7/24 (29.1%)	6/36 (16.7%)	
PICU transfers back to floor within 24 hours of admission	5/24 (19%)	2/27 (7.4%)	
Bounce back to PICU	1	0	