RESEARCH ARTICLE

An Assessment of Asthma Therapy in the Pediatric ICU

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ABSTRACT

OBJECTIVES: To describe asthma management, investigate practice variation, and describe asthma-associated charges and resource use during asthma management in the PICU.

METHODS: Children ages 2 to 18 years treated for status asthmaticus in the PICU from 2008 to 2011 are included in this study. This is a retrospective, single-center, cohort study. Data were collected by using the Intermountain Healthcare Enterprise Data Warehouse.

RESULTS: There were 262 patients included and grouped by maximal respiratory support intervention. Seventy percent of the patients did not receive escalation of respiratory support beyond nasal cannula or nonrebreather mask, and the majority of these patients received only first-tier recommended therapy. For all patients, medical imaging and laboratory charge fractions accounted for <3% and <5% of the total charges, respectively. Among nonintubated patients, the majority of these diagnostic test results were normal. Fifteen patients were intubated during our study period; 4 were intubated at our facility. Compared with outside hospital intubations, these 4 patients had longer time to intubation (>3 days versus <24 hours) and significantly longer median PICU length of stay (12.7 days versus 2.6 days).

CONCLUSIONS: In our study, the vast majority of patients with severe asthma were treated with minimal interventions alone (nasal cannula or nonrebreather mask and first-tier medications). Minimizing PICU length of stay is likely the most successful way to decrease expense during asthma care.

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www.hospitalpediatrics.org
DOI:https://doi.org/10.1542/hpeds.2017-0003

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HOSPITAL PEDIATRICS (ISSN Numbers: Print, 2154-1663; Online, 2154-1671).

FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: No external funding.

POTENTIAL CONFLICT OF INTEREST: The authors have indicated they have no potential conflicts of interest to disclose.

Drs M. Henderson and Bratton conceptualized and designed the study, drafted the initial manuscript, conducted the initial analysis, reviewed and revised the manuscript, designed the data collection instruments, coordinated and supervised data collection, and critically reviewed the manuscript; Dr Larsen conceptualized and designed the study and drafted the initial manuscript; Drs Schunk and J. Henderson reviewed and revised the manuscript; Mr Wilkes designed the data collection instruments and coordinated data collection; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Asthma is 1 of the most common chronic medical conditions in childhood, affecting ~7.1 million people with annual direct health care costs of ~$50 billion in 2014.[1] Although death because of asthma is declining,[2] asthma continues to be a common cause of ICU admission.[3,4]

The Global Initiative for Asthma, in association with the National Heart, Lung, and Blood Institute (NHLBI), has enumerated guidelines for the initial care of asthma exacerbations. These recommendations include inhaled short-acting β-agonists,[5–7] systemic corticosteroids,[8–10] ipratropium bromide before admission,[11] and oxygen.[12,13] In these guidelines, they also suggest considering several other medications for the treatment of asthma refractory to initial care (eg, terbutaline, methylxanthines, heliox, and nitric oxide), but recommendations are vague because of insufficient evidence for efficacy. Additionally, there is no consensus regarding indications for the use of noninvasive positive-pressure ventilation (NPPV), progression to invasive mechanical ventilation, or the optimal use of laboratory and radiographic testing during severe exacerbations. As a result, status asthmaticus management (medications, studies and respiratory support) remains widely variable.[14]

Using administrative data, we sought to (1) to describe asthma management at a single PICU, (2) investigate practice variation and resource use during severe asthma exacerbation management, and (3) describe asthma-associated charges in the PICU, grouped by level of maximal respiratory support interventions.

METHODS

Study Design

We conducted a retrospective, single-center, descriptive, cohort study of 262 children treated for status asthmaticus in the PICU at Primary Children's Hospital (PCH) in Salt Lake City, Utah. We assessed the charges related to various status asthmaticus therapies and associated diagnostic tests.

Data Source

Data were collected by using the Intermountain Healthcare Enterprise Data Warehouse (EDW) in Salt Lake City, Utah. The EDW database includes financial and clinical information collected from Intermountain Healthcare facilities, including PCH, which is a freestanding, 260-bed, level I pediatric trauma center with 44 000 emergency department (ED) visits annually. All EDW data were validated with a 10% patient chart review. The University of Utah Institutional Review Board approved this study and granted a waiver of the need for informed consent.

Patient Selection

All children with a primary discharge diagnosis of asthma (*International Classification of Diseases, Ninth Revision*, codes 493.0–493.9), aged 2 to 18 years, and treated in the PICU at PCH between 2008 and 2011 were evaluated. During this time period, continuous albuterol therapy mandated PICU admission, whereas subsequently, this practice was not universal. Those patients whose nonprimary discharge diagnostic code was asthma were not included. Those with additional *International Classification of Diseases, Ninth Revision* diagnosis codes for bronchiolitis (466.1–466.19, 487.1, or 491.8), chronic lung disease of the newborn (770.7), cystic fibrosis (277.0, 277.00, or 277.02), and myopathies (359.0–359.9) were excluded.

Study Variables

Demographic and clinical data were obtained as well as information regarding medications, laboratories, imaging, respiratory support modalities, and other clinical charges.

Medications

At the time of this study, grade A recommendations by the NHLBI for the treatment of status asthmaticus included the following: systemic corticosteroids, inhaled short-acting β-agonists, inhaled ipratropium bromide before hospital admission, and oxygen. These are referred to as first-tier therapies. Other medications, including inhaled ipratropium bromide after hospital admission, intravenous (IV) magnesium sulfate, IV β-agonists, IV methylxanthines, inhaled heliox, inhaled nitric oxide, and subcutaneous or inhaled epinephrine, were graded as B to D recommendations by the NHLBI and are referred to as second-tier therapies.

Laboratories

Laboratories that were evaluated included blood gas panels, complete blood counts (CBCs), chemistry panels, and magnesium levels. Blood gas panels included arterial, venous, and capillary blood samples and were labeled as "blood gas panel." Basic metabolic panels and renal function panels were also grouped together and labeled as "chemistry panel." Reference ranges for normal study values for infants and children were those reported by the clinical laboratory (Table 1).

Imaging

Only chest radiographs (CXRs) were included. Radiographic interpretations that included pneumonia, atelectasis, or pneumothorax were considered abnormal because these could potentially alter therapy.

Respiratory Support Modality

Patients were grouped by the highest level of respiratory support modality used (determined by charge codes or chart review). The patients were first broadly divided into 2 groups: (1) those who were not intubated (nonintubated) and (2) those who were intubated (intubated). The nonintubated group was then subdivided into 2 subsets: (1) nasal cannula or nonrebreather (NC/NRB) mask and (2) NPPV. There were no administrative codes for simple mask. The NPPV subset was further divided into 2 groups: (1) high-flow nasal cannula (HFNC) and (2) continuous positive airway pressure ventilation or continuous bilevel positive airway pressure ventilation (CPAP/BiPAP). The intubated group was also subdivided into 2 subsets: (1) Intermittent Mandatory Ventilation-Outside Hospital (IMV-OSH), indicating patients intubated at an outside hospital ED that is not staffed by pediatric emergency medicine physicians, and (2) Intermittent Mandatory Ventilation-Primary Children's Hospital, indicating those intubated at Primary Children's Hospital ICU.

All endotracheal intubations were determined by the presence of either a procedure code for intubation or a code for

TABLE 1 Values of Frequent Blood Tests and Respiratory Support Modality

	Nonintubated			Intubated	
	NC/NRB (n = 184)	NPPV		IMV-OSH (n = 11)	IMV-PCH (n = 4)
		HFNC (n = 26)	CPAP/BiPAP (n = 37)		
No. blood gases, Pco_2 <45 mm Hg (%)					
1	82/86 (95)	8/8 (100)	6/7 (86)	1/2 (50)	0
2–3	30/33 (91)	6/7 (86)	11/14 (79)	1/3 (33)	0/1 (25)
>4	10/10 (100)	6/6 (100)	8/11 (73)	0/6	0/3 (75)
No. CBCs, WBC >5 and <20 × 10^5 cells/μL^3 (%)					
1	29/34 (85)	9/12 (75)	12/15 (80)	2/2 (100)	0/2 (50)
2–3	4/6 (67)	0/4	4/4 (100)	2/3 (67)	0
>4	1/1 (100)	0/1	0/1	0/2	0/2 (50)
No. chemistry panels, potassium >3.4 and <4.7 mEq/L (%)					
1–2	49/72 (68)	8/10 (80)	15/22 (68)	4/4 (100)	0
3–4	8/16 (50)	6/9 (67)	2/5 (40)	0	0
4–9	2/4 (50)	0/1	0/2	2/3 (67)	0
>9	1/1 (100)	0	0	1/1 (100)	1/4 (25)

The carbon dioxide reference range is <45 mm Hg. The WBC reference range is 5–20 × 10^5 cells/μL^3. The potassium reference range is 3.4–4.7 mEq/L. The magnesium reference range is 1.5–3.5 mg/dL. WBC, white blood cell count.

mechanical ventilation, and these were verified by chart review.

Analysis

Descriptive data were summarized by median values, ranges, and interquartile ranges (IQRs) or percentages; categorical data were compared by using the χ^2 test. Statistical significance was defined as $P < .05$. Bonferroni adjustments were made for multiple pairwise comparisons, and the analysis was done with SPSS 22.0 (IBM SPSS Statistics, Armonk, NY).

RESULTS

A total of 262 patients met study criteria. Demographic features are shown in Table 2. White patients made up 72% of our cohort, which is representative of the population of Utah. All but 2 patients were discharged from the hospital to home. One patient went into cardiac arrest at an OSH and was pronounced dead at our facility. One patient with chronic disabilities was discharged to hospice care for reasons unrelated to asthma.

Patients grouped by their maximal level of respiratory support and their associated clinical and demographic data are shown in Table 3. One hundred eighty four patients (70%) did not receive escalation of respiratory support beyond NC/NRB mask. The majority (87%) of these patients were transferred out of the PICU in <3 days (median PICU length of stay [LOS], 1.2 days), which was significantly faster than children in the NPPV subset (Bonferroni adjustment for multiple pairwise comparisons). The NC/NRB subset also had significantly lower laboratory and medical imaging charges compared with the NPPV subset. When comparing patients who received CPAP/BiPAP to those who received HFNC, no significant differences were found in the quantities of laboratory tests, medical imaging charges, or PICU LOS.

Medians and IQRs for charges are shown in Table 4. As expected, total charges per admission increased with increasing PICU LOS. Median daily charges did not differ significantly when comparing the nonintubated subsets (NC/NRB versus NPPV). All charges, including median daily charges, were significantly less in the nonintubated group compared with the intubated group: nursing charges ($3725 vs $4145, respectively; $P = .044$), respiratory care charges ($715 vs $980, respectively; $P = .001$), pharmacy charges ($343 vs $602, respectively; $P < .001$), medical imaging charges ($73 vs $117, respectively; $P = .003$), and laboratory charges ($142 vs $254, respectively; $P = .002$). Across all groups, nursing charges accounted for the largest fraction of the total charges (62%–74%). In both the nonintubated group and the intubated group, medical imaging and laboratory charge fractions accounted for <3% and <5% of the total charges, respectively.

Only 15 (6%) patients were intubated. Eleven were intubated at OSH EDs (IMV-OSH subset), and the remaining 4 were intubated in the PICU at PCH (IMV-PCH subset). None were intubated in the ED at PCH. The 4 intubated patients in the IMV-PCH subset spent a median of 3 days in the hospital before intubation. All of those in the IMV-OSH subset were intubated early during the ED visit and had not received PICU care before transfer. Children in the IMV-OSH subset had a significantly shorter PICU LOS compared with those in the IMV-PCH subset (2.6 days versus 12.7 days, respectively; $P < .05$). Additionally, all patients in the IMV-PCH subset had a concurrent infection (pneumonia on the basis of radiographic findings, a positive respiratory culture result, or a positive respiratory viral screen result) compared with 64% of those in the IMV-OSH subset (determined by chart review). This variance was not statistically different (relative risk ratio, 1.5; 95% confidence interval, 1.0–2.5).

TABLE 2 Patient Demographics

	N = 262
Sex, n (%)	
Male	146 (56)
Female	116 (44)
Race, n (%)	
White	189 (72)
Hispanic	47 (18)
African American	7 (3)
Other	19 (7)
Age, y, median (range)	6 (2–17)
PICU LOS, d, median (range)	1.7 (0.2–14.8)
Hospital LOS, d, median (range)	3 (1–21)
Admitted through ED, n (%)	188 (72)
Disposition, n (%)	
Died	1 (0.5)
Hospice	1 (0.5)
Home	260 (99)

TABLE 3 Respiratory Support Modality and Associated Clinical and Demographic Data

	Nonintubated			Intubated	
	NC/NRB	NPPV		IMV-OSH	IMV-PCH
		HFNC	CPAP/BiPAP		
Total, *n* (%)	184 (70)	26 (10)	37 (14)	11 (4)	4 (2)
Age, y, median (range)	6 (2–17)	6 (2–14)	9 (2–15)[a]	6 (2–13)	4 (3–7)
PICU LOS, d, median (range)	1.2 (0.2–11.4)	3.6 (0.6–8.5)[a]	3.6 (1.0–9.0)[a]	2.6 (0.4–4.5)	12.7 (10.9–14.8)[b]
PICU LOS <24 h, *n* (%)	62 (34)	2 (8)	0	2 (18)	0
PICU LOS 1–3 d, *n* (%)	97 (53)	8 (31)	14 (38)	5 (45)	0
PICU LOS >3 d, *n* (%)	25 (14)	16 (62)	23 (62)	4 (36)	4 (100)
CXR and/or admission, median (range)	1.0 (0–1.0)	2.0 (1.0–4.0)[a]	1.0 (1.0–4.0)	3.0 (1.0–5.0)	15 (11.3–18.0)[b]
Laboratories and/or admission, median (range)					
Blood gas panel	1.0 (0–1.0)	1.5 (1.0–3.3)[a]	2.0 (1.0–4.0)[a]	4.0 (2.0–13.0)	27.0 (5.3–40.4)
CBC	0 (0–0)	1 (0–1.0)[a]	1.0 (0–1.0)[a]	1 (0–3.0)	2.5 (1.0–10.8)
Chemistry panel	1.0 (0–1.0)	1.5 (1.0–3.0)[a]	1.0 (1.0–2.0)[a]	2.0 (1.0–9.0)	13 (10.0–22.0)[b]

[a] Comparison groups include only those who never received invasive ventilation; $P < .0125$ for pairwise comparisons with the NC/NRB group.
[b] Comparisons are among only those receiving invasive mechanical ventilation.

As shown in Table 1, when laboratory results were evaluated, the majority of results among children in the nonintubated group were normal. Potassium was low in approximately one-third of children, but of these children, potassium was replaced only 6% of the time. Magnesium levels were obtained for 88 patients, but only 1.5% of these patients had levels >4 mg/dL. Of the children in the NC/NRB subset who had a single blood gas sample measured, 95% (82 of 86) had carbon dioxide levels <45 mm Hg.

Table 5 depicts the variation in medication use before and after PICU admission with associated median charges. The majority of patients in the NC/NRB subset received only the currently recommended first-tier therapies for asthma, with 41% receiving IV magnesium sulfate, <10% receiving IV terbutaline, and <1% receiving IV methylxanthines, inhaled heliox, inhaled nitric oxide, or subcutaneous and/or inhaled epinephrine. The median charges for ipratropium bromide were low ($8 and $22 for nonintubated and intubated patients, respectively). All patients in the IMV-PCH subset received ipratropium bromide before PICU admission compared with 55% of the patients in the IMV-OSH subset. In the nonintubated group, ipratropium bromide use before PICU admission was variable (65%–78%). Among all patients, magnesium sulfate and terbutaline were the most commonly used second-tier medications. Charges for terbutaline were substantially greater than for magnesium sulfate (intubated group median, $338 vs $179; nonintubated group median, $467 vs $106). In this study, methylxanthines, heliox, and nitric oxide were rarely used either before or after PICU admission. Epinephrine was not given to any patient in our cohort. In compliance with Global Initiative for Asthma recommendations, 100% of our cohort received systemic steroids and inhaled short-acting β-agonist.

DISCUSSION

In this study, we investigated the PICU management of asthma and discovered several interesting findings. We noted significant variation in the use of second-tier therapies but also noted that most PICU asthma admissions are managed with first-tier therapies alone. The largest contribution to PICU costs of care involves intubation and PICU LOS. There is little opportunity to decrease expenses by reducing imaging and laboratory testing because these account for small fractions of the total charges. It remains unclear what cost/benefit advantages or disadvantages would be incurred by a standardized use of second-tier medications.

In a 2007 study, researchers reported that patients in respiratory distress who were treated in a pediatric ED were more likely to receive a trial of NPPV (CPAP/BiPAP), which was associated with significantly lower rates of intubation.[15] Two Pediatric Health Information System database reports also revealed that CPAP/BiPAP use was associated with a lower risk of intubation[14] and additionally showed that children whose respiratory support progressed in the ICU from CPAP/BiPAP to intubation did not have longer LOS compared with children who were intubated in the ICU without a trial of CPAP/BiPAP.[16] Cumulatively, these studies support early trials of NPPV and might support the use of pediatric-specific EDs in an effort to avoid intubation.

Twenty-four percent of the patients in our study received NPPV (either HFNC or CPAP/BiPAP). Theoretically, the application of positive end-expiratory pressure through NPPV can improve exhalation by maintaining airway distending pressure; however, the positive end-expiratory pressure delivered via HFNC cannot be routinely measured and is affected by patient size, flow rate, and cannula seal. Our rates of CPAP/BiPAP use were similar to those in a recent multicenter report,[17] and the use of CPAP/BiPAP versus HFNC did not affect overall charges.

TABLE 4 Respiratory Support Modality and Associated Charges

	Nonintubated			Intubated	
	NC/NRB (n = 184)	NPPV		IMV- OSH (n = 11)	IMV-PCH (n = 4)
		HFNC (n = 26)	CPAP/BiPAP (n = 37)		
LOS, d, median (IQR)	1.2 (0.2–11.4)	3.6 (0.6–8.5)	3.6 (1–9)	2.6 (0.4–4.5)	12.7 (10.9–14.8)
ICU charge and/or admission, $, median (IQR)	7100 (5900–10 200)	20 000 (12 800–24 700)	21 100 (13 600–29 100)	14 000 (7400–23 300)	92 200 (76 700–98 600)
ICU charge per d, median (IQR)	5500 (4600–6700)	5800 (5000–6100)	5800 (5200–6400)	6300 (5800–6600)	6700 (6400–8000)
Total charges, %					
Nursing	72	74	70	62	64
Respiratory care	5	12	13	15	15
Pharmacy	5	4	6	10	10
Medical imaging	1	1	1	1	2
Laboratory	4	3	3	4	4
Gas panel	1	0.8	0.8	1.9	2.5
CBC	0.5	0.2	0.2	0.5	0.1
Electrolyte panel	1	0.7	0.4	1.3	1.2
Other laboratories[a]	1.5	1.3	1.6	0.3	0.2
Other charges[b]	13	6	7	8	5

[a] Other laboratories include magnesium and methylxanthine levels and other miscellaneous laboratories charged for during PICU stay.
[b] Other charges included ED, cardiac consultations, rehabilitation services, and other miscellaneous charges accrued during the calendar days of the PICU stay.

When other measures have failed, mechanically ventilating patients in status asthmaticus can unload fatigued respiratory muscles and aid in gas exchange. However, intubating and ventilating patients with asthma requires a high level of caution and skill because these patients might be acidotic, hypoxic, and fatigued. During our study, the intubation of patients with asthma at PCH was infrequent. Those requiring intubation had a median of 3 days of previous hospitalization and had concomitant radiographic-confirmed pneumonia or identified viral infections.

Because of the small sample of intubated patients in this study, we can only speculate about the reasons for observed differences between those intubated at an OSH versus at the study hospital. Providers with less pediatric experience may be intubating patients early without an adequate trial of pharmacologic therapies or NPPV. We do not have data from our region on the total number of patients with childhood asthma presenting to all OSHs, so we cannot determine the actual intubation rates to provide accurate comparisons. Patients who were intubated at an OSH were intubated for a shorter duration, but it is possible that these patients experienced severe but brief symptoms[18,19] that resolved quickly after intubation. It is also possible that pediatric specialists have a higher threshold for intubating patients with asthma and have more resources available to help prevent rapid decompensation and the need for intubation (eg, NPPV, sedation potentially required during NPPV, and experience with and access to second-tier asthma medications).

Other components to cost-effective care might involve the reassessment of PICU admission criteria for patients with asthma and decreasing unnecessary testing. Seventy percent of the patients in our cohort received only conservative respiratory support (NC/NRB), and the majority of these patients received only first-tier recommended medications for treatment. These findings, coupled with the infrequent need for intubation, reveal that these patients could be safely treated in a non-ICU setting, although this issue is complex because hospital resources and non-PICU levels of care are variable.

Contrary to our a priori impression, this study did not reveal that diagnostic testing is being significantly overused, but abnormal results were uncommon. Opportunities to significantly reduce expenses in this arena are modest. Second-tier medication use was variable in our study, which is consistent with multiple previous studies,[14,16,17] and their use requires careful balancing of risks (eg, myocardial ischemia, arrhythmias, nausea, and vomiting)[20] and benefits (eg, avoidance of severe hypoxia or respiratory arrest). Recently, researchers in a randomized trial of pediatric patients who had received first-tier asthma therapies but remained in moderate-to-severe respiratory distress compared the addition of a single 50-mg/kg dose of magnesium sulfate to terbutaline (given as a 10 μg/kg bolus followed by an infusion of 0.1 μg/kg per minute that could be escalated to 1 μg/kg per minute by increments of 0.1 μg/kg per minute) and aminophylline. The authors reported that significantly more children had clinical asthma scores improve by $\geq$3 points (maximum score of 15) within 1 hour if they received magnesium sulfate (97%) compared with terbutaline (70%) or aminophylline (70%) and remained significantly improved for 4 hours.[21] In our

TABLE 5 Respiratory Support Modality and Associated Medication Use and Charges

	Nonintubated			Intubated	
	NC/NRB (n = 184)	NPPV		IMV- OSH (n = 11)	IMV-PCH (n = 4)
		HFNC (n = 26)	CPAP/BiPAP (n = 37)		
Total ICU pharmacy charges, $, median (IQR)	352 (263–597)	817 (504–1426)	976 (521–1693)	1270 (864–2926)	8205 (4573–12 125)
Total ICU pharmacy charges per LOS d, $, median (IQR)	284 (211–371)	234 (170–452)	342 (253–425)	546 (412–1344)	$660 (349–1013)
Medications before PICU admission, n (%)					
Ipratropium bromide	144 (78)	17 (65)	27 (73)	6 (55)	4 (100)
Magnesium sulfate	76 (41)	13 (50)	21 (57)	5 (46)	3 (75)
Terbutaline	14 (8)	9 (35)	15 (41)	6 (55)	3 (75)
Methylxanthine	1 (0.5)	0	0	0	0
Heliox	1 (0.5)	0	3 (7)	0	0
Nitric oxide	0	0	0	0	0
Racemic epinephrine	0	0	0	0	0
Medications after PICU admission					
Ipratropium, n (%)	22 (12)	9 (35)	11 (30)	5 (45)	3 (75)
Ipratropium bromide charges, $ median (IQR)		8 (4–27)		22 (4–66)	
Magnesium sulfate, n (%)	21 (11)	7 (27)	14 (38)	3 (27)	3 (75)
Magnesium sulfate charges, $, median (IQR)[a]		63 (33–141)		179 (99–645)	
Terbutaline, n (%)	10 (5)	8 (31)	14 (38)	5 (46)	3 (75)
Terbutaline charges, $, median (IQR)[a]		467 (194–1469)		338 (204–814)	
Methylxanthine, n (%)	0	0	2 (5)	1 (9)	1 (25)
Heliox, n (%)	3 (2)	1 (4)	0	1 (9)	0
Nitric oxide, n (%)	0	0	1 (3)	0	0
Racemic epinephrine, n (%)	0	0	0	0	0

Methylxanthine is aminophylline or theophylline. All the patients received short-acting β-agonists and systemic corticosteroids.
[a] Among those who received the asthma therapy.

study, the use of aminophylline was low, but the charge information obtained for magnesium sulfate versus terbutaline (median magnesium sulfate charges [intubated group, $338 vs $179; nonintubated group, $467 vs $106]) suggests that magnesium is a less expensive second-tier choice; however, our study design does not allow for a comparison of effectiveness.

In our study, most patients received a CXR, but only 14% of the patients had a result that potentially would have altered therapy with findings of pneumonia, atelectasis, or pneumothorax. This is similar to a report by Narayanan et al.[20] These reports reveal that screening CXR is not needed unless there is concern for other complications.

Limitations of our study include that this is a single-hospital study, and some features (such as patient ethnicity) are not representative of the US pediatric population. This study also has inherent limitation related to its retrospective design. The number of intubated patients in our study was small and so lacks statistical power. The data came from a primarily administrative data set and present no objective measurement of asthma severity. Additionally, patients who did not present with asthma as the primary diagnosis were not included in this study, and we acknowledge that because of this, a certain group of patients with asthma might have been excluded in our analysis. There was also a possible selection bias with regard to which patients received the various available respiratory therapies because this decision was left to the clinical judgment of the attending physician and care team. Although charges for medications and therapies vary across the United States by region, we chose to report charges instead of costs because most hospitals do not have accurate cost accounting. There is a comparison metric within our hospital, but it is not meant to be specifically extrapolated to other institutions. In this study, charges for medications did not include dispensing fees or administration fees. Additionally, the reliability of this study is dependent on the accuracy of charges coded and diagnostic codes, which could be in error.

CONCLUSIONS

Minimizing PICU LOS appears to be the most successful way to deliver less expensive care to patients with severe asthma. Avoiding intubations may also decrease expense, assuming that LOS is not increased. The current literature reveals that an effective way to minimize intubation rates includes, when possible, treating pediatric patients in pediatric facilities

where additional recourses and skills are available, which could minimize exposure to potentially unnecessary intubations. Our data also reveal that most patients with asthma who are admitted to the PICU for asthma therapy require only first-tier therapies. Given the relatively infrequent need for subsequent intubation, these findings reveal that there may be options to treat these patients in a non-ICU setting, although additional studies would be needed to address the effectiveness and safety of this type of care outside of the PICU. We also note that there is relatively small opportunity for decreasing expense because of the overuse of laboratory and radiographic tests even during severe asthma exacerbations. Smaller savings could potentially be gained by minimizing second-tier medications; however, this benefit would be negated if there was a clear enhanced efficacy with the addition of each second-tier medication. If second-tier medications are warranted, magnesium sulfate may be a less expensive choice compared with terbutaline. In this study, we reiterate the need for more detailed guidelines for the appropriate use of NPPV, intubation, PICU admission criteria, and the responsible use of diagnostic tests and second-tier asthma medications during severe asthma exacerbations.

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