Journal of Intensive Care Medicine
2014, Vol. 29(3) 154-159

DOI: 10.1177/0885066613476446
jic.sagepub.com
SAGE

Patient Origin Is Associated With Duration of Endotracheal Intubation and PICU Length of Stay for Children With Status Asthmaticus

Shinpei Shibata, MD[1], Robinder G. Khemani, MD, MsCI[2], and Barry Markovitz, MD, MPH[2]

Abstract

Objective: To describe intubation practices and duration of mechanical ventilation in children with status asthmaticus admitted from emergency departments (ERs) to pediatric intensive care units (PICUs). **Design:** Retrospective cohort study using the Virtual PICU Performance System database (VPS, LLC) of children with status asthmaticus admitted to a participating PICU between December 2003 and September 2006. The primary outcome measure was intubation prior to intensive care unit (ICU) admission. Secondary outcomes included length of intubation and medical length of stay. **Setting:** Thirty-five PICUs in the United States. Patients: Children who were intubated and mechanically ventilated during their ICU stay for asthma and were admitted from an ER. **Results:** A total of 4051 patients with status asthmaticus were identified. Intubation data were available from 35 of the 53 centers. Of all, 187 children were intubated for asthma, of which 157 were admitted from an ER and had complete data. Of all, 85 patients were from community hospital ERs and 72 were from the institution's own ER. In all, 115 (73%) patients were intubated prior to ICU admission and 42 (27%) patients were intubated after PICU admission. Of patients who received mechanical ventilation for status asthmaticus and were intubated prior to PICU admission, a greater proportion were intubated at community hospital ERs than in the institutions' own ERs. Eighty-five percent of the patients from community hospital ERs were intubated prior to PICU admission as opposed to 60% from institution's own ERs ($P = .0004$). However, median duration of intubation and PICU stay from community hospital ERs was significantly shorter than from the hospitals' own ERs (25 vs 42 hours $P = .011$; 57 vs 98 hours $P = .0013$, respectively). Logistic regression analysis revealed that after controlling for the effects of age, race, gender, and a revised version of the Paediatric Index of Mortality score of patients who were admitted for status asthmaticus and required mechanical ventilations, patients treated in community hospital ERs represented a greater proportion of preadmission intubation. The odds ratio for preadmission intubation was 5.1 if the patients arrived from community hospital ERs (95% confidence interval 1.91-13.6). **Conclusion:** Patients with status asthmaticus are more likely to be intubated when they are admitted from community hospital emergency rooms, although the duration of intubation and PICU stay is shorter.

Keywords

Introduction

Asthma is the most common chronic illness among children.[1] Despite medical advancements over the years, the prevalence of pediatric asthma continues to rise.[1] According to national surveillance conducted by the Centers for Disease Control between 2001 and 2003 in the United States, asthma affected 8.2% of the children, outnumbering the prevalence in adults (6.7%).[2] This high prevalence of asthma not only results in significant burdens for patients, families, and providers managing the chronic nature of the disease but also acute exacerbations frequently mandate emergency department (ER) visits or admission to hospitals or intensive care units (ICUs). In fact, pediatric asthma is responsible for well over half a million

[1] Department of Critical Care Medicine, Oregon Health and Science University, Doernbecher Children's Hospital, Portland, OR, USA
[2] Department of Anesthesiology Critical Care Medicine, Children's Hospital Los Angeles, University of Southern California Keck School of Medicine, Los Angeles, CA, USA

Received June 28, 2012, and in revised form September 6, 2012. Accepted for publication September 10, 2012.

Corresponding Author:
Shinpei Shibata, Department of Critical Care Medicine, Doernbecher Children's Hospital, Mail code: CDRCP, 707 S.W. Gaines St., Portland, OR 97239-2901, USA.
Email: shibata@ohsu.edu

ER visits in the United States yearly and has steadily increased between 1994 and 2004.[2]

Given the high prevalence of asthma, some patients with status asthmaticus are admitted to the pediatric ICU (PICU) and present unique challenges for the pediatric intensivist.[1,3] Although most children with asthma will not require endotracheal intubation and mechanical ventilation,[4,5] it still remains a necessary supportive therapy. However, intubation and mechanical ventilation can expose asthmatics to serious adverse effects such as worsening bronchospasm, laryngospasm, pneumothorax, pneumomediastinum, atelectasis, ventilator-associated pneumonia, hypotension, and potentially worsen air trapping.[5-11] Therefore, careful consideration must be given to the decision to intubate children with asthma.

Moreover, given the wide variations in the treatment of asthma based on geographic location, available treatment modalities, or preferences and experience of providers in caring for children with asthma,[10,12] some children may be intubated earlier than others. This relationship has been shown to depend on the location of first presentation, as previously studied in a single-center retrospective cohort study by Carroll et al.[4] He and his colleagues have shown that children who received initial care at a community hospital ER were 3 times more likely to be intubated than those who were admitted from a tertiary care children's ER at Connecticut Children's Medical Center.[4]

We hypothesize that this relationship will hold across multiple institutions, and that children presenting to community hospital ERs are more likely to be intubated prior to PICU admission than those who present to children's hospital ERs.

Methods

This study was approved by the institutional review board at Children's Hospital Los Angeles. Deidentified patient data was obtained from Virtual PICU Performance System (VPC, LLC), a collaborative database comprised of 84 PICUs throughout the United States.

We reviewed the VPS database for all patients with a primary diagnosis of status asthmaticus between December 2003 and September 2006. Patients were included in the analysis if they had (1) a primary diagnosis of status asthmaticus, (2) were endotracheally or nasotracheally intubated at some point during their ICU stay, and (3) were admitted from an ER to the ICU. We excluded patients with tracheostomies because we thought that a physician's threshold to use mechanical ventilation would be different in this population. We also thought that excluding a comorbidity such as tracheotomy would yield a more typical asthma cohort. Medical length of stay (defined as when the patient was medically ready for discharge, as opposed to physical length of stay, when the patient physically left the unit) was chosen for analysis to avoid overestimation of PICU stay for those patients who stayed in PICUs because there was no ward bed available. Age, gender, and race were also included in our analysis. The primary outcome measure was the proportion of intubation prior to PICU admission. Secondary outcome measures were duration of mechanical ventilation and PICU length of stay.

Statistical Analysis

Statistical analysis was performed using Statistica v. 5.5 (StatSoft, Tulsa, Oklahoma) and Stata v. 10 (Statacorp, College Station, Texas). The data were first analyzed for distribution of variables and population characteristics. Proportions for categorical data such as gender, race, and ethnicity were compared by a Yates corrected chi-square test. Medians for continuous variables (presented with interquartile range, IQR) such as length of intubation and PICU length of stay were compared by Mann-Whitney U test, as data were not normally distributed. For the categorical variable of pre-ICU intubation, a multivariable logistic regression model was created to control the effects of confounding variables. Multivariate linear regression methods were used for analysis of continuous variables such as length of stay in the PICU and duration of mechanical ventilation. Variables were included in the multivariate model if they had a univariate association ($P < .2$) with the outcome measures (intubation before ICU admission, length of stay, length of mechanical ventilation) or if they were deemed to be a confounder on the relationship between the outcome measures and ER type (community vs tertiary care). Goodness of fit for the logistic regression model was analyzed using the Hosmer Lemeshow test. Assumptions of the linear regression model were examined and satisfied with the use of logarithmic transformations for length of stay and length of mechanical ventilation.

Results

Four thousand fifty-one patients had a primary diagnosis of status asthmaticus between December 2003 and September 2006. Out of this subset, 284 patients were intubated either by orotracheal, nasotracheal, or by tracheostomy tube. In all, 98 patients were excluded for being ventilated through a tracheostomy and 3 were excluded for incomplete or inconsistent data. A total of 183 patients with status asthmaticus were intubated during their hospitalization, of which 157 were admitted from a tertiary hospital emergency room (85 patients) or a community hospital emergency room (72 patients; Figure 1).

Demographic and severity of illness data of the 2 groups are presented in Table 1. There were more Caucasian patients admitted from community hospital emergency rooms than from tertiary hospital emergency rooms. The distribution of gender, age, revised version of the Paediatric Index of Mortality (PIM2) score, and other races were similar in both the groups.

Out of 157 patients, 115 (73%) patients were intubated prior to ICU admission and 42 (27%) were intubated after PICU admission. A greater proportion of the patients from the community hospital ERs were intubated before arrival to PICU (72 [85%] of 85 vs 43[60%] 72). The relative risk of intubation if a patient is coming from a community hospital ER was 1.42 (95% confidence interval [CI] 1.15-1.75). However, median duration of intubation (25 hours; IQR 7-74 vs 42 hours; IQR

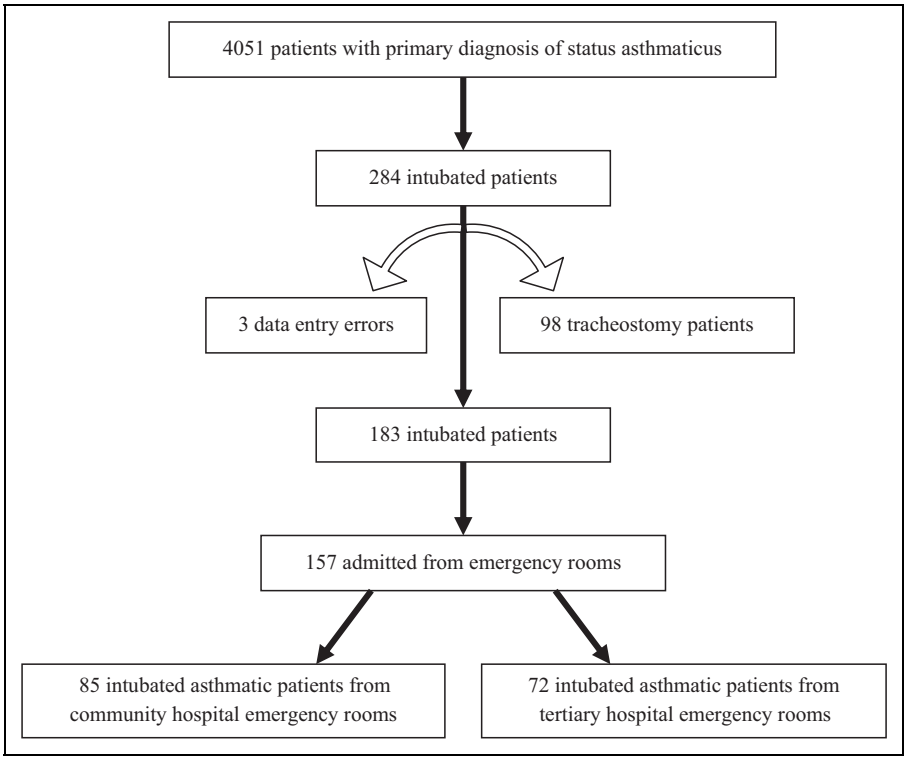

Figure 1. Flowchart of screening, inclusion, and exclusion criteria.

Table 1. Demographic Data of Children With Status Asthmaticus Admitted From Community Hospital ERs and Tertiary Hospital ERs.[a]

	Community ER, N = 85	Tertiary ER, N = 72	*P* Value
Male	47 (55%)	47 (65%)	.267
Caucasian	43 (51%)	21 (29%)	.011
African American	24 (28%)	29 (40%)	.155
Other/missing ethnicity data	18 (21%)	22 (31%)	.246
Age	9.0 (3.8, 9.2)	7.3 (3.5, 8.2)	.188
PIM2 probability of death	0.009 (0.007, 0.015)	0.008 (0.003, 0.019)	.288

Abbreviations: ER, emergency department; PIM2, a revised version of the Paediatric Index of Mortality.

[a] Categorical data presented as number and percentage and analyzed with a Yates corrected chi-square test. Continuous data presented as median and interquartile range, and analyzed with a Mann Whitney *U* test.

18-113 hours, $P = .011$) and PICU length of stay (57 hours; IQR 33-117 vs 98 hours; IQR 52-184 hours, $P = .0013$) from the community hospital ER group was significantly shorter than the tertiary hospital ER group (Table 2). There were only 3 deaths identified out of the 157 patients and they were all from tertiary hospital ERs.

Logistic regression analysis revealed that among all intubated asthmatics, after controlling for the effects of age, race, gender, and PIM2 score, patients admitted from a community hospital were 5.1 times (95% CI 1.91-13.6) more likely to be intubated pre-PICU admission (Table 3). Moreover, shorter duration of intubation and overall PICU length of stay for patients admitted from community hospital ERs held true even after controlling for the effects of age, race, gender, and PIM2 score with multivariate linear regression ($P < .02$; Table 4).

Discussion

In this cohort of children intubated for asthma, we found that patients from community hospital ERs were more likely to be intubated prior to PICU admission than those admitted from a tertiary care institutions' own ERs, although the duration of intubation and PICU stay was significantly shorter. These findings held even after controlling for possible confounding factors such as age, race, gender, and PIM2 score. In fact, patients admitted from community hospital ERs had a 5.1 times increased odds of intubation before PICU admission compared to those admitted from tertiary care ERs.

These findings may indicate that (1) physicians at community hospital emergency rooms have a lower threshold to intubate asthmatics, (2) physicians at community hospitals might have chosen to intubate electively to protect the airway for transport safety reasons, or (3) the shorter duration of hospital stay and mechanical ventilation may suggest that early intubation of status asthmaticus might have been beneficial, resulting in better outcomes. However, evaluation is needed before we can interpret the third possible explanation as valid, because intubating asthmatics has long been considered risky rather than therapeutic, potentially resulting in higher morbidity and mortality.[5-11] The findings from a retrospective cohort

Table 2. Rate of Intubation Prior to PICU Arrival, Duration of Intubation, and PICU Length of Stay Based on Admission Locations.[a]

	Community ER, N = 85	Tertiary ER, N = 72	
Intubation on arrival to PICU	72 patients (85%)	43 patients (60%)	RR = 1.42, 95% CI (1.15-1.75)
Duration of intubation	25 hours (7-74 hours)	42 hours (18-113 hours)	$P = .011$
Length of stay in PICU	57 hours (33-117 hours)	98 hours (52-184 hours)	$P = .0013$

Abbreviations: ER, emergency department; PICU, pediatric intensive care unit.
[a] Continuous data presented as median and interquartile range, and analyzed with a Mann Whitney *U* test.

Table 3. Multivariate Logistic Regression Model on the Outcome of Intubation Prior to ICU Arrival.

	Odds Ratio (95% CI)
Community hospital ER	5.1 (1.91-13.6)
Caucasians	1.0 (control)
African Americans	3.9 (1.17-13.0)
Other ethnicities	1.04 (0.34-3.12)
Age in years	1.1 (0.98-1.17)
Female	0.81 (0.33-2.03)
PIM2 score	3.60 (2.13-6.02)

Abbreviations: CI, confidence interval; ER, emergency department; ICU, intensive care unit; PIM2, a revised version of the Paediatric Index of Mortality.

Table 4. Multivariate Regression Analysis Summary of Dependent Variables for Length of Stay in PICU and Duration of Intubation.

	Length of Stay in PICU		Duration of Intubation	
	Coefficient (B)	*P* Value	Coefficient (B)	*P* Value
Community hospital ER	−0.50	.0024	−0.60	.027
PIM2 score	−0.16	.019	−0.048	.67
Age	−0.0023	.072	−0.0058	.0082
Gender	−0.052	.74	−0.27	.31
African American	0.079	.69	0.10	.75
Other ethnicity	−0.16	.41	0.19	.56

Abbreviations: ER, emergency department; PICU, pediatric intensive care unit; PIM2, a revised version of the Paediatric Index of Mortality.

study by Roberts et al suggest that PICUs that use mechanical ventilations more often, defined as "high-use centers," were an independent predictor for longer PICU stay and hospital stay, even after adjustment was made for Pediatric Risk of Mortality III scores, age, degree of hypercarbia, and respiratory rate.[12] There is obviously a subgroup of asthmatics for whom intubation is life saving, but what many would consider premature intubation of status asthmaticus is not justifiable from the results of our retrospective study.

Recently, several studies identified a subgroup of patients with status asthmaticus, known as rapid progressive asthma or acute asphyxiating asthma.[13,14] These patients deteriorate quickly but clinical improvement is fast once appropriate medical therapy is initiated. Maffei and his colleagues showed in their retrospective study that among all intubated asthmatic children, those who had rapid respiratory failure, defined by intubation en route, on arrival, or within 30 minutes of arrival to their ER, improved faster than those who were intubated later in the ER or PICU.[14] Mean duration of mechanical ventilation for the rapid respiratory failure group was significantly shorter compared to those who were intubated later (29 ± 43 vs 88 ± 72 hours, $P = .006$). This was consistent with the results from an adult ER study by Rodrigo et al. This prospective cohort study involving 403 adults showed that a group with rapid-onset asthma (duration of symptoms less than 6 hours) showed greater improvement as evidenced by serial measurements of peak expiratory flow and forced expiratory volume in 1 second after the same amount of bronchodilator was administered. Also, they showed that the rate of hospital admission was lower in the rapid onset group.[13] Such a subgroup of acute asphyxiating asthma could only confound our results if there was a reason to believe that more patients with acute asphyxiating asthma present to community hospital ERs than tertiary care ERs. Although this is a theoretic possibility, it would be unlikely to completely explain our results.

Our findings echo those of Carroll et al, who found that at a single institution the rate of intubation was higher in patients referred from a community hospital ER than those from a children's hospital ER (17% vs 5%; $P = .004$).[4] They also found that children intubated at a community hospital ER had a shorter duration of mechanical ventilation (71 ± 73 vs 151 ± 81 hours; $P = .02$) and a shorter PICU length of stay (129 ± 82 vs 230 ± 84 hours; $P = .01$).[4] We have now confirmed these findings with multiinstitutional data from across the country, with a larger cohort of patients. Given the well-described differences in outcome and disease severity for asthma based on race and socioeconomic status,[3,15] we felt it was important to evaluate a multivariate model controlling for race, gender, age, and PIM2 score. Our study demonstrates that being African American was an independent risk factor to be intubated prior to ICU arrival with an odds ratio of 3.9 (1.17, 13.0). In general, African American children tend to have more severe and recurrent exacerbations of asthma than Latinos, Caucasians, or other racial and ethnic groups.[3,15] This difference seems to be multifactorial and likely represents a combination of genetic, socioeconomic, environmental factors, and availability of preventive care.[3,15,16] In our study, more Caucasian children presented to community hospital ERs (51%) than to tertiary hospital ERs (29%; $P = .001$). Large academic institutions and tertiary hospitals tend to be located in urban

areas in this country, where there may be a higher density of minority groups.

The limitations of this study are largely related to its retrospective design. Calculating the true rate of intubation was not possible since the data set only contained patients who were admitted to PICUs. Presumably, most patients with status asthmaticus are admitted to regular pediatric wards, not to PICUs. Without an accurate denominator, we were not able to calculate the true intubation rate for status asthmaticus.

Also, the VPS database did not include what types of therapy were administered before intubation. Carroll et al showed in their retrospective study that a community hospital ER was less aggressive in terms of therapies before intubation. However, due to their small sample size, it did not reach statistical significance.[4]

Although we controlled for PIM2 score, we did not have data on baseline asthma severity for individuals. While PIM2 scores reflect the condition of a patient immediately on PICU admission, it does not account for the asthma severity, and in fact status asthmaticus is a "low-risk" diagnosis for the PIM2 score.[17]

Given that these data were gathered from multiple institutions with different personnel, there certainly could be data entry errors. The VPS has undertaken many steps to ensure data integrity, including training modules, periodic audits, site visits as well as automated algorithms to catch aberrancies in the data. Nonetheless, there were 3 patients who needed to be excluded secondary to incomplete or inaccurate data. There certainly could have been more data errors that we did not detect with our data integrity checks. Unfortunately, this is una-voidable when dealing with large databases.

Another variable that would have been fascinating to include in the analysis is the rate of complications from intubation. It is well described in several studies that intubation of an asthmatic patient is inherently high risk.[5-11] However, there are very few pediatric descriptive studies indicating the rate of complications. This is likely because of the small number of asthmatics who need mechanical ventilation. Finally, the distance between community hospital ERs and the referral centers would have been another interesting piece of information. It would have helped to quantify whether distance was a determining factor for intubation for safety during the transport.

In conclusion, we have shown that children with status asthmatics who present to community hospital ERs are more likely to be intubated before PICU admission than those who present to tertiary hospital ERs, even after controlling for several potential confounding factors such as race, age, gender, and PIM2 score. Moreover, patients admitted from community hospital ERs had shorter duration of PICU stay and length of mechanical ventilation. We speculate that physicians at community hospital ERs may have a lower threshold to intubate children with status asthmaticus or they decided to intubate electively for airway protection before transport. Perhaps, education of community hospital ER physicians on more aggressive medical management could help prevent unnecessary intubations for children with asthma and potentially avoid complications of mechanical ventilation and other morbidities.

Acknowledgements

No endorsement or editorial restriction of the interpretation of these data or opinions of the authors have been implied or stated by VPS, LLC.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

References

1. Centers for Disease Control and Prevention (CDC). Asthma mortality and hospitalization among children and young adults–United States, 1980-1993. *JAMA*. 1996;275(20):1535-1537.
2. Moorman JE, Rudd RA, Johnson CA, et al. National surveillance for asthma–United States, 1980-2004. Centers for Disease Control and Prevention (CDC). *MMWR Surveill Summ*. 2007;56(8): 1-54.
3. Pirie J, Cox P, Johnson D, Schuh S. Changes in treatment and outcomes of children receiving care in the intensive care unit for severe acute asthma. *Pediatr Emerg Care*. 1998;14(2):104-108.
4. Carroll CL, Smith SR, Collins MS, Bhandari A, Schramm CM, Zucker AR. Endotracheal intubation and pediatric status asthmaticus: site of original care affects treatment. *Pediatr Crit Care Med*. 2007;8(2):91-95.
5. Graham AS, Chandrashekharaiah G, Citak A, Wetzel RC, Newth CJ. Positive end-expiratory pressure and pressure support in peripheral airways obstruction: work of breathing in intubated children. *Intensive Care Med*. 2007;33(1):120-127.
6. Carroll CL, Zucker AR. The increased cost of complications in children with status asthmaticus. *Pediatr Pulmonol*. 2007; 42(10):914-919.
7. Dales RE, Munt PW. Use of mechanical ventilation in adults with severe asthma. *Can Med Assoc J*. 1984;130(4):391-395.
8. Mansel JK, Stogner SW, Petrini MF, Norman JR. Mechanical ventilation in patients with acute severe asthma. *Am J Med*. 1990;89(1):42-48.
9. Zimmerman JL, Dellinger RP, Shah AN, Taylor RW. Endotracheal intubation and mechanical ventilation in severe asthma. *Crit Care Med*. 1993;21(11):1727-1730.
10. Roberts JS, Bratton SL, Brogan TV. Acute severe asthma: differences in therapies and outcomes among pediatric intensive care units. *Crit Care Med*. 2002;30(3):581-585.
11. Mansel JK, Stogner SW, Petrini MF, Norman JR. Mechanical ventilation in patients with acute severe asthma. *Am J Med*. 1990;89(1):42-48.
12. Roberts JS, Bratton SL, Brogan TV. Acute severe asthma: differences in therapies and outcomes among pediatric intensive care units. *Crit Care Med*. 2002;30(3):581-585.
13. Rodrigo GJ, Rodrigo C. Rapid-onset asthma attack: a prospective cohort study about characteristics and response to emergency department treatment. *Chest*. 2000;118(6):1547-1545.
14. Maffei FA, van der Jagt EW, Powers KS, et al. Duration of mechanical ventilation in life-threatening pediatric asthma:

description of an acute asphyxial subgroup. *Pediatrics*. 2004; 114(3):762-767.

15. Rodríguez MA, Winkleby MA, Ahn D, Sundquist J, Kraemer HC. Identification of population subgroups of children and adolescents with high asthma prevalence: findings from the Third National Health and Nutrition Examination Survey. *Arch Pediatr Adolesc Med*. 2002;156(3):269-275.
16. Smith LA, Hatcher-Ross JL, Wertheimer R, Kahn RS. Rethinking race/ethnicity, income, and childhood asthma: racial/ethnic disparities concentrated among the very poor. *Public Health Rep*. 2005; 120(2):109-116.
17. Slater A, Shann F, Pearson G, Paediatric Index of Mortality (PIM) Study Group. PIM2: a revised version of the Paediatric Index of Mortality. *Intensive Care Med*. 2003;29(2):278-285.