

Comparison of treatment modalities for inpatient asthma exacerbations among US pediatric hospitals



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Clinical Implications

- When comparing treatment for inpatient pediatric asthma hospitalizations, there is significant variability in treatment with magnesium sulfate, ipratropium bromide, terbutaline, heliox, bilevel positive airway pressure, and mechanical ventilation for pediatric intensive care unit admissions across US pediatric hospitals.

TO THE EDITOR:

Asthma is a leading cause of hospitalization in children.^{1,2} Known risk factors for asthma exacerbations include demographic factors, atopic status, second-hand smoke exposure, and obesity.³⁻⁵ Frontline therapies to treat an acute asthma exacerbation include corticosteroids and bronchodilators.^{6,7} Guidelines for the management of asthma, including outpatient exacerbations, have been widely promoted in the United States and Europe. The Global Initiative for Asthma published guidelines in 2016 for asthma management in children and adults.⁶ These guidelines include recommendations for inpatient care, specifically short-acting β_2 -agonist, oxygen, and corticosteroids for moderate to severe exacerbations, and consideration of other therapies for those unresponsive to frontline therapies.⁶ However, many hospitals develop local evidence and experience-based asthma pathways to treat asthma,⁸ particularly in the intensive care setting, which may reflect the paucity of data related to effective inpatient management.

Although it has been suggested that pediatric intensive care unit (PICU) level care for pediatric asthma may have regional variation,⁹ the variation between pediatric hospitals across the United States has not been examined. We aimed to determine the treatment variation for asthma in PICUs among US pediatric hospitals using a nation-wide claims database of pediatric hospitals.

We evaluated inpatient hospitalizations to the PICU for asthma using the Pediatric Health Information System (PHIS) database, a multi-institutional database that includes data collected from inpatient admissions and emergency department visits from 43 free-standing US children's hospitals spread across the geographic United States. Forty hospitals were included in the analysis; hospitals without inclusive data for the time period queried were excluded. We queried discharge data from January 2010 to December 2014 for children 6-11 years of age admitted with a primary diagnosis, based on International Classification of Diseases, 9th revision (ICD-9), of acute asthma exacerbation or

status asthmaticus (ICD-9 codes 493, 493.01, 493.02, 493.1, 493.11, 493.12, 493.9, 493.91, or 493.92). Admissions were excluded if patients had other cardiac, pulmonary, or neuromuscular disorders that impact breathing and transfer hospitalizations.

We queried demographic information for patients, asthma medications used, and respiratory support measures provided for each admission. Intraclass correlations (ICCs) were estimated with random intercept logistic regression models using Stata 13.1 (StataCorp LP, College Station, Tex). Shrinkage estimates from the mixed effects models were reported to account for variability due to hospitals with small sample sizes.

In total, 5330 PICU admissions for asthma across the 40 hospitals were included in the analysis. During the study period, PICU admissions for asthma per hospital ranged from 21 to 462 (median = 115, interquartile range = 46-160). In total, 61% of patients were male with a median age of 8 years. Black race comprised 57% of the population with 23% white, 19% other, and 12% Hispanic ethnicity. The average length of hospitalization was 3 days, whereas the average length of stay in the PICU was 1 day. Medicaid was the primary payer for 79% of admissions, whereas health maintenance organization (HMO) and preferred provider organization (PPO) each comprised 10% of admissions. A total of 99.9% of patients were discharged, whereas 0.1% (7 patients) died during hospitalization. Characteristics of admitted patients are shown in [Table E1](#) (available in this article's Online Repository at www.jaci-inpractice.org).

For each treatment measured, rates of treatment use varied significantly across hospitals (all $P < .001$). For PICU admissions, hospital level variability explained a considerable amount of the total variability of each treatment method, with ICCs ranging from 0.14 for magnesium sulfate to 0.71 for helium oxygen (heliox). [Table 1](#) demonstrates the percentile of all PICU admissions using a specific treatment modality in hospitals at the 25th, 50th, and 75th percentile. Ipratropium bromide and magnesium sulfate were the most common treatments, but between-hospital variability explained 52% of the total ipratropium bromide variability compared with only 14% of the total magnesium sulfate variability. Terbutaline was used less frequently than both ipratropium bromide and magnesium sulfate. Heliox was used less frequently than all other therapies, with 71% of the variability explained at the hospital level. Use of modes of respiratory support was also variable across hospitals, including noninvasive positive-pressure ventilation (includes continuous positive airway pressure and bilevel positive airway pressure [BiPAP]) and mechanical ventilation. BiPAP was used more frequently than mechanical ventilation for all PICU admissions, and mechanical ventilation had greater variability of use among hospitals studied. The PHIS database does not allow determination of the sequence that medications or therapies were given. [Figure 1](#) demonstrates treatment variation across hospitals for PICU admissions.

Our analysis focused on medications beyond standard frontline therapies (short-acting β_2 -agonist, corticosteroids, and oxygen), as these medications are widely accepted and used in the management of moderate to severe asthma exacerbations. For PICU admissions, use of all medications and respiratory support

TABLE I. Variation in medication and treatment use between hospitals, 2010-2014

Treatment	Percentage of hospitals using treatment, PICU admissions*			
	25th%ile	50th%ile	75th%ile	ICC [95% CI]
Terbutaline	5.5	13.8	26.2	0.31 [0.22, 0.42]
Ipratropium bromide	67.8	91.4	95.0	0.52 [0.40, 0.64]
Magnesium sulfate	64.7	74.9	81.8	0.14 [0.09, 0.22]
Heliox	0.2	1.5	7.0	0.71 [0.56, 0.82]
BiPAP	5.1	9.2	28.7	0.37 [0.26, 0.50]
Mechanical ventilation	2.0	6.3	13.4	0.52 [0.38, 0.65]

BiPAP, Bilevel positive airway pressure; CI, confidence interval; ICC, intraclass correlation; PICU, pediatric intensive care unit.

*Use of medication for each hospital in the database was reported after using shrinkage estimates to account variability due to hospitals with small sample sizes.

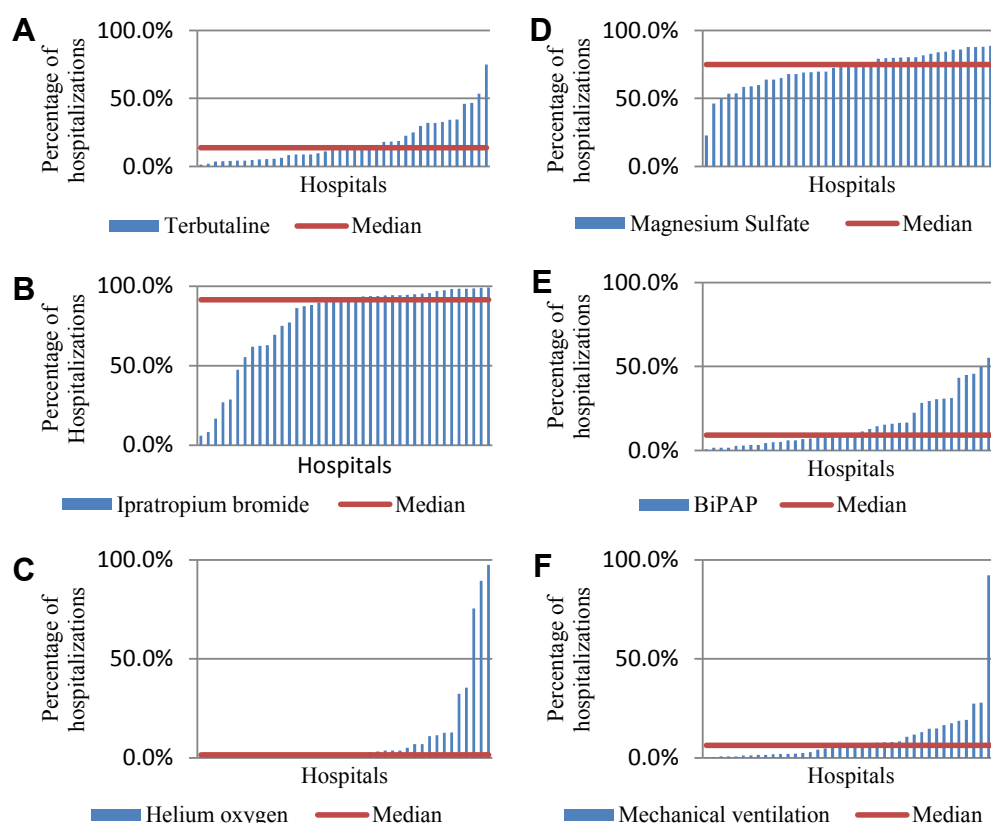


FIGURE 1. Variation in use of medication and respiratory support measures across hospitals for PICU admissions, 2010-2014. Each bar represents a single US pediatric hospital. Use of medication for each hospital in the database was reported after using shrinkage estimates to account variability due to hospitals with small sample sizes. **A**, Terbutaline; **B**, ipratropium bromide; **C**, helium oxygen; **D**, magnesium sulfate; **E**, BiPAP; **F**, mechanical ventilation. BiPAP, Bilevel positive airway pressure; PICU, pediatric intensive care unit.

measures varied widely across hospitals, highlighting the lack of uniformity in approaching critically ill patients with asthma. The implications of these treatment variations across hospitals are not entirely known, but may lead to variable patient outcomes. Given the level of acuity of patients who are admitted to the PICU with the highest potential for morbidity and mortality, this analysis highlights the need for more evidence-based standardized approaches to treatment.

We focused on hospitalizations involving admission to a PICU as we were interested in more severe asthma exacerbations that may require medications that are not guideline based. We

focused our analysis on ages 6-11, excluding ages 2-5 and children 12 and over. Asthma management may differ slightly in each age group, which could skew the data. Using the multi-center national PHIS database to analyze variability in PICU practice offers the great advantage of allowing for evaluation of discrete trends of what would otherwise be rare events for individual institutions. However, determining health care trends by administrative data has several limitations. Treatments delivered are based on billing data, so errors in data entry or coding may lead to incorrect data; however, the large sample size should minimize the effect of any small aberrations in coding.

Additionally, PICU admission criteria may vary from center to center based on experience and resources, similar to the level of acuity of a patient who seeks care. We attempted to minimize this potential bias by excluding hospital transfers and significant patient comorbidities.

We demonstrated that medication use and respiratory support measures vary greatly between institutions, especially medications beyond frontline therapies including corticosteroids, albuterol, and oxygen. Treatments used for severe asthma exacerbations are quite variable between hospitals. Future analyses should determine outcomes based on treatment variations for asthma exacerbations. Research efforts should focus on the development of guideline-based management of severe asthma exacerbations.

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APPENDIX

TABLE E1. Demographic characteristics (n = 5330)

	N (%) or median (IQR)
Males	3245 (61)
Age (y)	8 (7, 10)
Race/ethnicity	
White	1202 (23)
Black	3024 (57)
Hispanic	625 (12)
Other	479 (9)
Primary source of payment	
Medicaid	3418 (79)
HMO	435 (10)
PPO	448 (10)
Length of stay (d)	3 (2, 4)
PICU length of stay (d)	1 (1, 2)
APR-DRG severity level	
Minor (1)	1929 (36)
Moderate (2)	2308 (43)
Major (3)	903 (17)
Extreme (4)	190 (4)
Average	1.9
Outcome	
Discharged	5145 (99.9)
Death	7 (0.1)

APR-DRG, All patients refined - diagnosis related groups; HMO, health maintenance organization; IQR, interquartile range; PICU, pediatric intensive care unit; PPO, preferred provider organization.

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