

ORIGINAL CONTRIBUTION

PRAM Score as Predictor of Pediatric Asthma Hospitalization

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Abstract

Objectives: The objective was to determine the association between asthma severity as measured by the Pediatric Respiratory Assessment Measure (PRAM) score and the likelihood of admission for pediatric patients who present to the emergency department (ED) with moderate-to-severe asthma exacerbations and who receive intensive asthma therapy.

Methods: This was a secondary analysis of a prospective study of triage nurse-initiated steroid therapy in pediatric asthma. Children aged 2 to 17 years inclusive, presenting with moderate-to-severe acute asthma exacerbations (defined as PRAM ≥ 4), were included. To be eligible for inclusion in the study, children must have received "intensive asthma therapy," defined as nurse-initiated initial bronchodilator and oral steroid therapy at arrival to triage. PRAM scores were measured hourly as per ED protocol. The primary outcome was inpatient hospitalization; secondary outcome was ED stay greater than 8 hours. Logistic regression models were used to predict admission based on PRAM score at triage and then hourly thereafter. The area under the receiver operating characteristic curve (AUC) was calculated for each hour.

Results: A total of 297 patients were included in the analysis, with an admission rate of 11.4% for patients receiving intensive therapy. The 3-hour PRAM (AUC = 0.85) significantly improved prediction of admission compared to PRAM at triage ($p = 0.04$).

Conclusions: The 3-hour PRAM scores best predicts the need for hospitalization. These results may be applied in clinical settings to facilitate the decision to admit or initiate more aggressive adjunctive therapy to decrease the need for hospitalization.

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Numerous validated scores, including the Pediatric Respiratory Assessment Measure (PRAM) score, Pediatric Asthma Severity Score, and Respiratory rate-Accessory muscle use-Decreased breath sounds (RAD) score, have been used to classify asthma severity and treatment.¹⁻⁴ The PRAM score incorporates the components of wheezing, air entry, contraction of scalenes, suprasternal retraction, and oxygen saturation into a validated scale for use in children 2 to 17 years of age presenting with acute asthma exacerbations. It has been demonstrated to be a responsive and discriminative tool with good intra- and interrater reliability.³ Despite

validated scores to guide evidence-based management, there remains significant underuse of proven asthma treatments, as emphasized in three recent U.S. and Canadian studies.⁵⁻⁷ In addition to the burden on patients and families, there is an enormous economic burden to pediatric asthma; up to 45% of asthma health care costs are associated with emergency department (ED) visits and inpatient hospital care.⁸ With upwards of 30% of the children presenting to the ED with acute asthma eventually requiring hospital admission, it is a leading cause of hospitalization.^{9,10} The application of evidence-based "intensive asthma therapy," defined as the receipt of

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systemic corticosteroids plus three albuterol treatments with ipratropium within 1 hour of triage, has been shown to decrease ED length of stay, as well as hospital admission.^{7,11}

Early identification of the best predictors of hospitalization has the potential to improve ED patient flow by allowing physicians to standardize the timing for the decision to admit for pediatric asthma. There have been attempts to predict the need for hospital admission using clinical variables measured at triage or after initial ED asthma treatment.^{3,4,12–15} However, there are limitations with the existing literature examining prognostication for pediatric asthma admission. First, the majority of studies do not incorporate intensive asthma therapy; specifically, most patients did not receive systemic corticosteroid within 1 hour of presentation, an intervention that has been shown to decrease odds of hospital admission.^{16,17} Further, the prediction literature includes patients presenting with mild asthma exacerbations who are at low risk of needing admission.^{3,6}

To date, no published studies have examined the ability of a validated clinical score to predict admission for patients who received standardized evidence-based asthma therapy with full compliance. We hypothesize that the PRAM score would best predict risk for hospitalization when measured after the initiation of evidence-based therapy compared to at triage. An ability to predict hospital admission based on PRAM score would help with ED patient flow management and may also encourage the initiation of more aggressive therapy to decrease the need for hospitalization in this subset of high-risk patients. The primary objective was to determine the hour of the ED visit when the PRAM score best predicts the need for hospitalization. As a secondary outcome, we wanted to determine if there was superiority of the posttriage PRAM scores to triage PRAM, since the existing literature often used a severity score derived at triage in the predictive model.^{3,4,14} Additionally, as prolonged time spent in the ED would help with resource allocation and utilization, we wished to determine at which hour of the ED visit the PRAM score best predicts a prolonged ED stay. A prolonged ED stay was defined as greater than or equal to 8 hours from time of arrival in patients who are eventually discharged from the ED without admission.

METHODS

Study Design

This study was a retrospective cohort study of ED visits for asthma. It was a secondary analysis of data collected for a study examining the effectiveness of an asthma medical directive in the ED that permitted nurses to initiate corticosteroid administration at triage.¹¹ In this study, asthma severity was assessed by measuring PRAM scores at triage, and treatments were initiated by triage nurses prior to physician assessment. Ethics approval for this secondary analysis was obtained from the local research ethics board.

Study Setting and Population

All patients included in this study presented to pediatric ED of the Children's Hospital of Eastern Ontario

(CHEO), Ontario, Canada, between February and May 2010. CHEO is a tertiary care center with an annual ED census of approximately 68,000 visits and approximately 2,500 patient visits per year for asthma.

Inclusion and exclusion criteria from the parent study were applied. Briefly, children were eligible if they were between 2 and 17 years of age inclusively and presented with moderate to severe acute asthma exacerbations (defined as triage PRAM score ≥ 4). Patients must have received a prior diagnosis of asthma by a physician or have three or more episodes of wheezing responsive to beta-2 agonists (consistent with the Canadian Pediatric Asthma Consensus Guidelines and the Global Initiative for Asthma guidelines).^{18,19} Children with PRAM scores < 4 (mild exacerbation) or > 11 ; with hypersensitivity to dexamethasone or oral corticosteroids; with chronic respiratory conditions such as bronchopulmonary dysplasia or cystic fibrosis; cardiac, metabolic, or immunologic disease; or history of adrenal suppression were excluded. Other exclusion criteria included patients with coexisting acute illness such as pneumonia, pertussis, or croup; any use of oral corticosteroid in the past 14 days; and exposure to varicella in the previous 3 weeks in a susceptible child.

Patients who did not receive intensive asthma therapy based on their presenting triage PRAM scores were also excluded from our study. Intensive asthma therapy was defined for moderate exacerbations (PRAM 4 to 7, inclusive) as three initial salbutamol treatments via metered dose inhaler using a valved spacer along with oral corticosteroid administration by the triage nurse between the first and second inhaled treatments (which may be prior to physician assessment). Intensive asthma therapy was defined for severe exacerbations (PRAM 8 or greater) as three inhaled salbutamol plus ipratropium bromide treatments via nebulization along with oral corticosteroid administration by the triage nurse between the first and second treatment (which may be prior to physician assessment). In all cases, oral systemic corticosteroids plus all three initial inhaled treatments were administered within 1 hour of patient arrival at triage.

Study Protocol

Asthma Medical Directive. Prior to the introduction of the corticosteroid medical directive, our team had past experience using a multidisciplinary approach to asthma through a medical directive permitting bronchodilator initiation. This directive incorporated the PRAM in triage decision-making for initiation of bronchodilator therapy and ensured that nurse decision-making capacity was based on a validated and reliable tool while allowing decisions to be made within nursing scope of practice. Training on the PRAM was performed over 1 year and included grand rounds and nursing education sessions. Further, a pediatric emergency medicine (EM) asthma nurse champion was responsible for updating all nurses on asthma-related care, assisted by a pediatric EM nurse educator responsible for training all new hires on the application of all ED medical directives. All physicians were trained during grand rounds and divisional rounds and were required to sign off on approval of the medical directive. The additional training to implement the nurse-initiated steroid component of the medical directive was

performed over 1 month during pediatric EM nursing education sessions and by the pediatric EM nurse educator. Operationally, triage nurses initiate the asthma medical directive based on the PRAM score measured in the triage bay. The initial bronchodilator therapy and oral corticosteroid is subsequently administered in the patient's room (in the event that the patient is placed immediately in an ED room), at triage, or in the waiting room if an ED room is not immediately available. The medical records of all children with International Classification of Diseases, 10th Revision (ICD-10), discharge diagnoses of asthma over a 4-month period (February 2010 through May 2010) were examined to determine eligibility.

A standardized case report form was used for data abstraction. Data collected during the study included: 1) triage time; 2) the PRAM score assigned by the nurse to the patient at time of triage and at approximately 2, 3, and 4 hours or until admission or discharge (given the nature of ED care, we recorded the actual time of PRAM score measurement as care of other patients may have resulted in minor time deviations); 3) time of administration of oral steroid; 4) time of inhaled beta-2 agonist, inhaled anticholinergic, and other medications; 5) time of discharge from ED; 6) time of physician decision to admit; 7) time of admission to inpatient unit; and 8) duration of inpatient stay. Potential confounders such as age and previous hospitalizations to the ward or pediatric intensive care unit (PICU) were documented. The primary investigator trained two reviewers and oversaw the initial data collection. Interrater reliability of chart abstractors was assessed by duplicate sampling of 5% of included charts.^{20,21}

Data Analysis

Variables were summarized using frequencies and proportions (discrete) or medians and interquartile ranges (IQRs) for continuous variables. Univariate logistic regression models were used to predict admission based on PRAM score at triage and 2, 3, and 4 hours. Goodness of fit of these models was assessed using the le Cessie-van Houwelingen test.^{22,23} We did not examine the association of PRAM score at 1 hour with hospital admission, as patients would have just completed their initial bronchodilator therapy. The area under the receiver operating characteristic (ROC) curve (AUC) for each fitted logistic regression model was computed and used to determine at which time points the PRAM score provided the best predictions.²⁴ The same method was used for the outcome of prolonged stay (greater than 8 hours). Comparisons of AUC based on PRAM score at triage and PRAM score at each of 2, 3, and 4 hours were made using the method of DeLong et al.,²⁵ which takes into account the correlation of the AUCs that occurs because they are based on the same group of patients. Two-sided p-values less than 0.05 were taken to be statistically significant. p-values were adjusted for multiple testing using Holm's method.²⁶

RESULTS

During the study period, 587 patients were treated for asthma, and 297 patients with moderate to severe

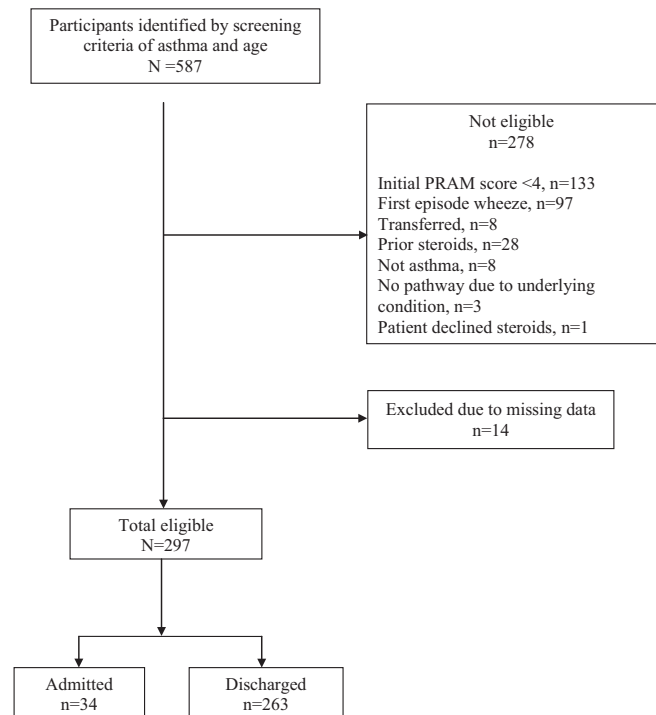


Figure 1. Patient flow. PRAM = Pediatric Respiratory Assessment Measure.

asthma met the study inclusion criteria (Figure 1). Tables 1 and 2 outline the included patients' baseline characteristics and outcomes and compare them with patients who were subsequently hospitalized. The median PRAM score at triage was 7 (moderate; IQR = 5.0 to 8.0). A total of 152 patients (51%) were classified as severe asthma exacerbation with PRAM ≥ 8 as shown in Table 1. All patients received salbutamol and systemic corticosteroids. The median time to receive systemic corticosteroids was 28 minutes (IQR = 15 to 43 minutes). Twenty-one patients (7.4%) received magnesium sulfate as part of asthma management. Thirty-four patients (11.4%) required hospitalization. The median duration of admission was 45 hours (IQR = 32.7 to 66.8 hours). Of those patients who were discharged, the median ED length of stay was 304 minutes (IQR = 224 to 412 minutes). Thirty-three patients (11.1%) stayed in the ED for more than 8 hours and were subsequently discharged home (Table 2). Patients who required hospital admission had higher rates of previous hospital and PICU admissions for asthma compared to the rest of our cohort (Table 1). Most (85.2%) of the hospitalized patients received supplemental oxygen at some point throughout their ED stays, compared to 18.2% of the overall cohort (Table 2).

PRAM Score and Association With Admission

Out of the initial 297 patients, 195, 197, and 167 patients completed PRAM measurements at 2, 3, and 4, hours, respectively (because patients with rapid improvement to intensive therapy were discharged). PRAM measurements at 2 and 3 hours were equally the best predictors of need for hospitalization (Table 3), with AUC of 0.85 (2 hours, 95% confidence interval [CI] = 0.77 to 0.92;

Table 1
Patient Characteristics

Characteristic	Total, N = 297*	Admitted, n = 34
Age (years), median (IQR)	4.7 (2.8–7.6)	4.7 (3.0–8.5)
Male, n (%)	193 (65.0)	24 (70.6)
History of present illness		
Days of respiratory distress, n (%)	[n = 271]	[n = 31]
1	186 (68.6)	24 (70.6)
2	55 (18.5)	3 (8.8)
3 or more	30 (11.1)	4 (11.8)
Documented upper respiratory tract infection preceding this visit (%)	165 (55.6) [n = 221]	26 (76.5) [n = 31]
Treated for this episode prior to ED visit with, n (%)		
Salbutamol	260 (87.5) [n = 293]	30 (88.2)
Inhaled corticosteroid chronic (≥ 2 weeks)	124 (41.8) [n = 265]	16 (47.1)
Inhaled corticosteroid only with this episode	29 (9.8) [n = 263]	6 (17.6)
Documented oral montelukast	29 (9.8) [n = 295]	4 (11.8)
Documented antibiotics	8 (2.7) [n = 296]	0 (0%)
Past medical history and home environment, n (%)		
Documented personal history of asthma/eczema/environmental allergies?	269 (90.6) [n = 278]	32 (94.1)
Documented family history of asthma/eczema/environmental allergies?	162 (54.5) [n = 189]	27 (79.4)
Documented previous admission to hospital for wheezing/asthma	102 (34.3)	18 (52.9)
Documented admission to hospital for wheezing, past 12 months	50 (16.8)	10 (29.4)
Documented past ICU admission for wheezing	16 (5.4)	6 (17.6)
Physical examination findings at triage		
O ₂ percentage, median (IQR)	96.0 (94.0–97.0) [n = 296]	93.0 (91.0–95.0)
O ₂ < 92%, n (%)	25 (8.4) [n = 296]	24 (70.6)
Temperature, median (IQR)	36.5 (36.0–37.1) [n = 277]	36.5 (36.0–37.3)
Triage PRAM, median (IQR)	7.0 (5.0–8.0)	8.5 (7.0–10.0)
Triage PRAM ≥ 8 , n (%)	152 (51.1)	25 (73.5)

IQR = interquartile range; PRAM = Pediatric Respiratory Assessment Measure.
*N = 297 unless otherwise noted.

Table 2
Patient ED Management and Outcome

Variable	Total, N = 297* (%)	Admitted, n = 34 (%)
Supplemental oxygen (any)	54 (18.2)	29 (85.3)
Salbutamol	297 (100.0)	34 (100)
Ipratropium bromide	156 (52.5)	33 (97.1)
Systemic steroid given	297 (100.0)	34 (100.0)
Oral dexamethasone	289 (97.3)	30 (88.2)
Oral prednisolone	6 (2.0)	2 (5.9)
IV corticosteroids	14 (4.7)	13 (38.2)
IV magnesium	21 (7.4)	18 (52.9)
Time to receipt of steroids from triage (min), median (IQR)	28 (15–43)	31 (20.5–45.5)
Time to “mild” status from triage (min), median (IQR)†	209 (135–346)	—
Time to discharge from triage (min), median (IQR)	304 [n = 263] (224–412)	—
Hospital admission	34 (11.4)	—
Long ED stay > 8 hours	33 (11.1) [n = 263]	—
Returned to ED within 7 days for asthma	11 (4.2) [n = 263]	—
Subsequently admitted to hospital	2 (18.1) [n = 11]	—
Admission duration in hours, median (IQR)‡	45.4 (32.7–66.8) [n = 34]	—

IQR = interquartile range.
*n = 297 unless otherwise noted.
†Mild status defined as PRAM < 4.
‡Admission duration from time of transfer to inpatient ward to hospital discharge.

and 3 hours, 95% CI = 0.79 to 0.93) as shown in Figure 2. Of the hourly scores, the triage PRAM was the least predictive for the need for admission, with an AUC of 0.76 (95% CI = 0.67 to 0.84; Figure 2).

For direct comparison with the triage score, after correcting for multiple testing, only the 3-hour PRAM

was significantly better than PRAM at triage ($p = 0.04$). The 2- and 4-hour PRAM had p -values of 0.10 when compared with the triage PRAM score. For example, a PRAM score of ≥ 8 at 3-hours has sensitivity of 50%, a specificity of 98%, and a positive predictive value of 73% in predicting hospitalization (Table 4).

Table 3
PRAM Score Predictability Odds Ratios

Time	Odds Ratio (95% CI)	Test of Goodness-of-fit* p-value
PRAM as a predictor of admission		
Triage	1.82 (1.42–2.35)	0.15
2-hour	1.84 (1.47–2.29)	0.88
3-hour	2.05 (1.57–2.68)	0.87
4-hour	1.85 (1.46–2.35)	0.37
PRAM as a predictor of long ED stay > 8 hours		
Triage	1.26 (1.03–1.55)	0.79
2-hour	1.41 (1.14–1.74)	0.29
3-hour	1.49 (1.20–1.86)	0.25
4-hour	1.50 (1.20–1.88)	0.16

PRAM = Pediatric Respiratory Assessment Measure.

*Ie Cessie-van Houwelingen test for goodness of fit.

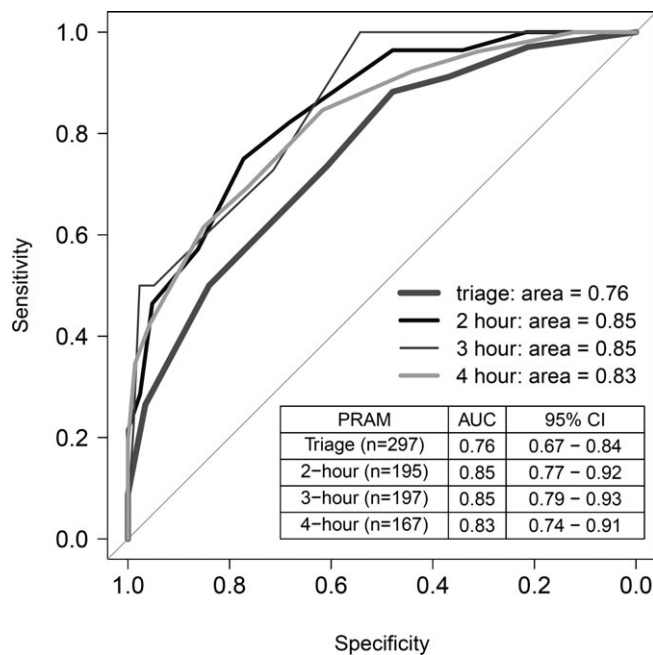


Figure 2. AUC for PRAM as a predictor for admission. AUC = area under the receiver operating characteristic curve; PRAM = Pediatric Respiratory Assessment Measure.

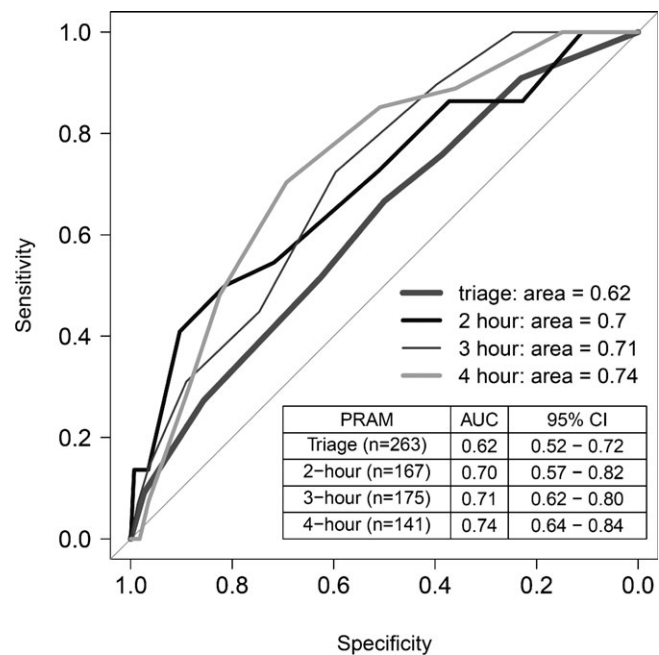


Figure 3. AUC for PRAM as a predictor for long ED stay > 8 hours. AUC = area under the receiver operating characteristic curve; PRAM = Pediatric Respiratory Assessment Measure.

Table 4
Sensitivity, Specificity, and PPV for Predicting Admission Using PRAM at Various Times

PRAM ≥	Triage			2-hour			3-hour			4-hour		
	Sens.	Spec.	PPV	Sens.	Spec.	PPV	Sens.	Spec.	PPV	Sens.	Spec.	PPV
6	91	37	16	75	77	36	59	86	34	62	85	43
7	88	48	18	57	86	41	50	95	55	42	96	65
8	74	61	20	46	95	62	50	98	73	35	99	82
9	50	84	29	29	98	67	23	99	71	19	100	100

All data are percentages.

PPV = positive predictive value; PRAM = Pediatric Respiratory Assessment Measure; Sens = sensitivity; Spec = specificity

PRAM Score and Association With Prolonged ED Stay
To evaluate the association of PRAM score and prolonged ED stay, of the initial 297 patients, 263 were

discharged home. Of these discharged patients, 167, 175, and 141 patients completed PRAM measurements at 2, 3, and 4 hours, respectively. The 4-hour PRAM

was the best predictor for long ED stay >8 hours, with AUC of 0.74 (95% CI = 0.64 to 0.84; Figure 3). However, when adjustment was made for multiple testing, 4-hour PRAM was no better than triage PRAM ($p = 0.08$; Table 3). The triage PRAM was the least predictive, with an AUC of 0.62 (95% CI = 0.52 to 0.72; Figure 3).

DISCUSSION

To the best of our knowledge this is the first study to include only patients presenting with moderate to severe asthma exacerbations who received standardized intensive asthma therapy (previously shown to decrease rates of hospitalization).²⁷ While all hourly PRAM scores predicted admission to varying degrees, only the 3-hour PRAM outperformed the triage PRAM score in predicting the need for admission.

The clinical assessment of acute asthma exacerbations has two different dimensions. A static assessment determines asthma severity on presentation, and a dynamic assessment determines response to therapy.²⁸ There is conflicting evidence regarding the predictability of clinical assessments at triage and hospitalization. Geelhoed et al.⁸ showed that a saturation <91% at triage had a 96% predictability of hospitalization. A recent database study by Horeczko and Wintemute²⁹ examining 2,454,983 pediatric ED visits for asthma contradicted this finding by demonstrating that vital signs at triage including oxygen saturation were not good predictors for hospital admission, with the exception of a low diastolic blood pressure.²⁹ A severe PRAM score (≥ 8) at triage has been shown to have a greater than 50% likelihood for hospital admission in patients with asthma.³ Dynamic assessments that can assess a patient's clinical progression and response to therapy are better at predicting need for hospitalization.^{3,30} A study by Schuh et al.¹⁵ suggested that clinical evaluation 2 hours after triage is the best predictor; however, this study did not include a validated score.

By applying dynamic assessment using PRAM to predict hospitalization, physicians may decide to admit high-risk patients earlier, thus freeing more emergency beds and helping patient flow. This has the potential to improve hospital-based resource utilization, quality improvement, and the ED's throughput benchmarking. Further, the literature has shown that physicians underutilize adjunctive therapies after the initial management.^{11,15} Magnesium sulfate has been shown to be effective in decreasing admission and improving bronchoconstriction and clinical symptoms of moderate-to-severe acute asthma,^{31,32} but is vastly underutilized even in tertiary academic pediatric EDs.⁷ Greater use of adjunctive therapy (such as magnesium sulfate) based on the 3-hour PRAM scores might help prevent admission and decrease overall health care costs.^{31,33} Future research opportunities exist in this domain with prospective studies that could examine the validity of clinical pathways incorporating the 3-hour PRAM evaluation to guide the decision to begin adjunctive therapy and in the decision to admit.

LIMITATIONS

This was a secondary analysis of data that was collected from retrospective chart extraction and as such is dependent on documentation in the medical record. The decision to admit by the treating physician was based on clinical judgment rather than instruction to apply measured variables. Finally, PRAM assessments were not available for all patients every hour.

CONCLUSIONS

This study shows the importance of dynamic assessment in acute asthma using Pediatric Respiratory Assessment Measure scores as good objective measures of clinical progression. These assessments have good predictability of hospital admission and long ED stay. The Pediatric Respiratory Assessment Measure score at 3 hours after presentation should be taken into consideration to improve ED patient flow and in patients who have not had maximized therapy, to initiate more aggressive measures to prevent hospitalization.

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