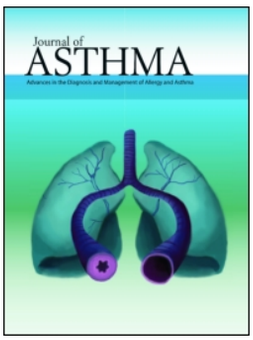

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Pediatric asthma severity scores distinguish suitable inpatient level of care for children admitted for status asthmaticus

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ABSTRACT

Objective: To determine if the Pediatric Asthma Severity Score (PASS) can distinguish "late-rescues" (transfer to the pediatric intensive care unit [PICU] within 24-hours of general pediatric floor admission), "PICU readmissions" (readmission within 24-h after transfer to a lower inpatient level of care), and unplanned 30-day hospital readmission in children admitted with status asthmaticus.

Methods: We performed a single center, retrospective cohort study in 328 children admitted for asthma exacerbation aged 5–18 years from May 2015 to October 2017. We sought to determine if PASS values preceding admission from the emergency department or transfer to the general pediatric unit will be greater in children with late rescues and PICU readmissions and if a cutoff PASS values exist to discriminate these events prior to intrafacility transfer.

Results: Nine (5%) late-rescues and 5 (3%) PICU readmissions accounted for 14/328 (4%) composite outcomes. PASS values were greater in children with these events (8 [IQR:5–8] vs. 5 [IQR:3–6], $p < .01$). Logistic regression of PASS on composite outcome yielded an odds ratio of 1.4 (1.1–1.8, $p < .01$) and ROC curve of PASS on a composite outcome yielded an AUC of 0.74 (0.61–0.87) with a threshold of ≥ 9. Nine (3%) children experienced unplanned 30-day hospital readmissions but PASS preceding hospital discharge was neither discriminative nor associated with hospital readmission.

Conclusions: PASS values ≥ 9 identify children at increased risk for late-rescue and PICU readmission. Applied with traditionally criteria for selection of inpatient level of care, PASS may assist providers in reducing acute inpatient disposition errors.

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Asthma; inpatient level of care; late rescue; pediatric asthma severity score; pediatric intensive care unit; unplanned readmission

Introduction

In the United States, pediatric asthma has a prevalence of 9.1% (~6.7 million children), accounts for 700,000 annual emergency department (ED) visits, and is the primary diagnosis for approximately 200,000 annual hospitalizations (1–3). Unplanned hospital readmission rates are reported in up to 40% of asthma-related encounters (2–6). Several readmission risk factors have been identified and include socioeconomic status, race, comorbid chronic medical conditions, previous asthma-related hospitalizations, and absent pulmonary medical homes (5–7). Similarly, selecting a suitable inpatient level of care upon hospitalization from the ED and timing for the transfer to a lower level of care from the pediatric intensive care unit (PICU) without a subsequent acute escalation of services remains challenging. Clinical deterioration requiring PICU escalation within 24-h of general pediatric floor admission ("late-rescues") and PICU readmission within 24-h of transfer to the general pediatric floor ("PICU readmissions") are noted in our institution in 6% of children hospitalized for asthma exacerbation (8).

Recent data suggest illness severity scoring tools, such as Pediatric Early Warning Score, may be superior to clinical judgement in discriminating deterioration of hospitalized patients (9). While asthma severity scores have been developed for clinical and research subject stratification, they have yet to be clinically validated beyond the purpose of disposition from the ED to either home or the inpatient setting (10–16). The pediatrics asthma severity score (PASS) is a commonly used metric calculated (Table 1) using respiratory rate, oxygen, auscultation, and work of breathing criteria (17). High PASS has been noted in

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Table 1. Pediatric Asthma Severity Score adapted from Gorelick et al. (17).

Score	0	1	2	3
Respiratory rate				
2–3 years of age	≤ 26	27–34	35–39	≥ 40
4–5 years of age	≤ 24	25–30	31–35	≥ 36
6–12 years of age	≤ 20	21–26	27–30	≥ 31
> 12 years of age	≤ 18	19–23	24–27	≥ 28
Oxygen requirement	≥ 98% on room air	95–97% on room air	90–94% on room air	< 90% on room air or on supplemental O2
Auscultation	Normal aeration	Minimal end-expiratory wheezing	Notable expiratory wheezing	Inspiratory + expiratory wheezing, or diminished breaths
Retractions	None	1 site	2 sites	≥ 3 sites
Dyspnea	None	Speaks in sentences, coos and babbles	Partial sentences, short cry	Single words, short phrases, grunting

children with longer duration of continuous albuterol treatment, noninvasive ventilation (NIV), and PICU hospitalization (18).

At this time, there are no data to suggest PASS can discriminate clinical outcomes such as suitable level of inpatient disposition from the ED, appropriate timing of PICU de-escalation, or unplanned, same cause hospital readmission. We sought to determine if PASS threshold values can reliably distinguish a composite outcome of late-rescues and PICU readmissions in children admitted for status asthmaticus in our institution. We hypothesize threshold PASS values exist that distinguish children with late-rescues and PICU readmissions.

Materials and methods

Study design and population

We performed a single center, retrospective cohort study from May 2015 through October 2017 including all children aged 5–18 years with the primary diagnoses of acute asthma exacerbation and/or status asthmaticus. Exclusion criteria were presence of an existing tracheostomy, chronic lung disease, pulmonary hypertension, cyanotic congenital heart disease, acute ED encounters without hospital admission, or hospitalization without documented PASS data. Children < 5 years of age were excluded to ensure a homogeneous sample as it is difficult to retrospectively discriminate asthma from bronchiolitis in young children. During the study period, compliance with PASS documentation was 98%. All research activities were conducted within a 259-bed, university-affiliated, tertiary pediatric referral center. This study was reviewed and approved by our local institutional review board.

Institutional PASS and asthma practice

At our center, children admitted for acute asthma exacerbation follow a clinical pathway including documentation of PASS at a minimum of every 4 h during admission and prior to and after all nebulized and metered dose inhaler treatments (Table 1). Prior to a patient transfer to a different unit, a PASS score is documented. The documentation and calculation of PASS is performed by trained respiratory therapists through the electronic health record. Children receiving interventions requiring a higher degree of monitoring such as noninvasive ventilation (NIV), continuous albuterol nebulization, vasoactive agents, inhaled heliox, or mechanical ventilation are admitted to the PICU. Prior to May of 2015, the Asthma Severity Score (19) was used until implementation of PASS (17). As a result we did not assess subjects prior to May of 2015. Children with asthma exacerbation admitted to the PICU receive a pulmonology consultation to establish a patient-centered medical home and improve discharge follow up rates. Inpatient level of care is determined by our emergency department (ED) providers in collaboration with intensive care and hospitalist subspecialties. Similarly, children admitted to the PICU are transferred to a lower level of care at the discretion of the intensivist in partnership with pediatric hospitalists and pulmonologists. Per hospital protocol, transfer to a lower level of care (the general pediatric floor) is encouraged once nebulized albuterol treatments are reduced to every 2 h for a minimum of two treatment intervals and no other PICU-level interventions (described above) are anticipated. During the study period, PASS values were not used as admission criteria in the ED or as "safe" transfer criteria to a lower level of care for inpatient units.

Study measures and definitions

The primary study outcome was a composite of PICU readmissions and late-rescues. PICU readmissions were defined as readmission to the PICU within 24-h of transfer to a lower level of care. Late-rescues were defined as acute escalation of care within 24-h of

admission to the general pediatric floor requiring transfer to the PICU. As both late-rescues and PICU readmissions are infrequent and represent a cognitive misrepresentation of patient stability, clinical trajectory, and inpatient services needed, a composite score was chosen for study. A secondary outcome was unplanned, same-cause 30-day hospital readmission. Additional descriptive data included PASS values, demographics, comorbidities, National Heart Lung and Blood Institute (NHLBI) asthma severity classification, inpatient medications (e.g. terbutaline, magnesium sulfate, ketamine, aminophylline, montelukast, subcutaneous epinephrine), respiratory therapeutic interventions (oxygen supplementation, inhaled heliox, NIV [e.g. bilevel positive airway pressure, continuous positive airway pressure, or heated, humidified, high flow nasal cannula], and invasive ventilation), extracorporeal life support (ECLS), length of stay (LOS), PICU LOS, and index mortality.

Data collection

Subjects were identified by our local Health Informatics department that queried billing and data warehouse databases for the primary admission diagnoses and presence of at least two PASS values during hospitalization. Discrete and explicit data fields were electronically compiled using the data warehouse and Virtual PICU Systems© database (Virtual PICU Systems, LLC, Los Angeles, CA). Any remaining data deficits were manually extracted by research team members and internal validation performed.

Statistical analysis

Descriptive data are reported as proportions, means ± standard deviations, or medians (interquartile range, IQR) depending on data type and variance. Data distributions were assessed using the Shapiro–Wilk test. Specific study cohorts for the entire sample were intended for three specific sets of comparative assessments including evaluations of: (1) children with and without the study composite outcome, (2) children with and without late-rescues, (3) those with and without PICU readmissions, and (4) those with and without 30-day same cause hospital readmissions. In addition, a composite comparative assessment of children with and without late-rescues and PICU readmissions was performed. Comparative statistics included Fisher's exact, student's *t*, Wilcoxon rank-sum, and paired testing as indicated. Threshold PASS values were identified using receiver operator characteristic (ROC) curves with reported area under the curve (AUC). Logistic regression was used to assess PASS associations with the composite outcome and unplanned hospital readmission with odds ratios (95% confidence interval, CI) reported. Type I error was set .05 and all comparative tests were two-sided. Analyses were completed using Stata© v15.1 software (Stata, College Station, TX).

Results

Sampling and general characteristics

During the study period, 328 children were included for study (Figure 1). Of those 54% ($n = 179$) were initially admitted to the general pediatric floor and 45% ($n = 149$) to the PICU. The PICU cohort size was ultimately 158 subjects as 9/179 (5%) children admitted to the general pediatric floor required escalation of care to the PICU during their hospital stay. Study sample and cohort-specific demographic data, NHLBI asthma severity classification, historical asthma severity risk factors, comorbidities, and secondary admission diagnoses are shown in Table 2. As expected, a higher proportion of children with severe asthma were admitted to the PICU than the general pediatric floor using the incidence of NHLBI classification of moderate and severe persistent asthma (58% vs. 38%, $p < .01$) and presence of historical asthma severity risk factors including outpatient medication noncompliance (29% vs. 15%, $p < .01$) and history of previous PICU admission (40% vs. 19%, $p < .01$). A summarization of inpatient medications, respiratory interventions, and general hospital outcomes are listed in Table 3. Nine children (3%) were intubated for mechanical ventilation. No mortality or ECLS were observed in our sample.

Data for the study composite outcome and ROC curve analyses

Median PASS values immediately preceding disposition from the ED or PICU to the general pediatric floor were greater in children with incidence of subsequent composite outcome (8 [IQR: 5–8] vs. 5 [IQR: 3–6], $p < .01$). Simple logistic regression of PASS values prior to disposition from the ED or PICU to the general pediatric floor on incidence of composite outcome yielded an odds ratio of 1.4 (95% CI:1.1–1.8, $p < .01$). ROC curve (Figure 2) of PASS immediately preceding admission from the ED or PICU transfer to a lower level of care on the incidence of study composite outcomes yielded an AUC of 0.74 (95% CI:0.61–0.87) with a threshold PASS value ≥ 9.

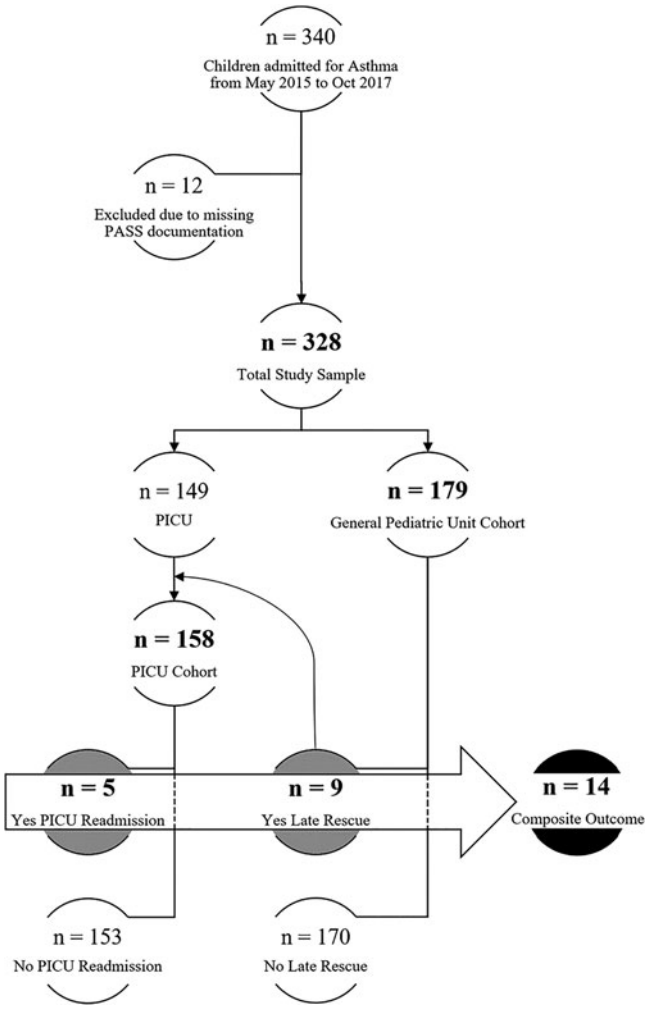

Figure 1. Flow diagram of study sample and cohorts.

Data for late-rescue cohort

Nine of the 179 subjects (5%) admitted to the general pediatric floor represented late-rescues with escalation to the PICU within 24-h of admission. These transfers occurred at a mean of 6.7 ± 3.9 h after hospital admission and 33% between 7 pm–7 am. Children with late-rescue had a PICU LOS of 1.1 ± 0.6 days and all were eventually transferred to a lower level of care prior to hospital discharge without a subsequent PICU readmission. Upon PICU admission, two patients were placed on NIV and seven received an isolated bolus of magnesium sulfate. No other interventions were observed after transfer. Children with and without late-rescue did not differ with respect to mean age (9.2 ± 3.5 vs. 8.7 ± 3.4 years, $p = .69$), weight (48.3 ± 30 vs. 36.7 ± 20.9 kg, $p = .11$), gender ratio (1.3:1 vs. 1.4:1, $p > .99$), NHLBI asthma severity classification, historical asthma severity risk factors, comorbidities, or secondary hospital diagnoses. The late-rescue cohort had a greater hospital LOS (2.6 ± 0.9 vs. 1.3 ± 0.7, $p < .01$) and incidence of oxygen supplementation at the time of hospital admission (89% vs. 33%, $p < .01$) than those admitted to the general pediatric floor without a late rescue.

Median PASS values immediately preceding hospital admission from the ED were greater in those with late-rescue as compared to those without (8 [IQR: 7–8] vs. 6 [IQR: 4–7], $p = .01$). Median first documented PASS values after admission to the general pediatric floor remained higher in the late-rescue cohort (8 [IQR: 6–10] vs. 6 [IQR: 4–7], $p < .01$). Unadjusted logistic regression of PASS preceding hospital admission on the subsequent late-rescue yielded an odds ratio of 1.42 (95% CI: 1.02–1.90, $p = .03$).

Data for PICU readmission within 24-h cohort

Of the 158 subjects admitted to the PICU, 143 (91%) were transferred to a lower level of care prior to hospital discharge. Among those patients, five (3%) children were readmitted to the PICU within 24-h at a

Table 2. Total study sample, general pediatric floor, and pediatric intensive care unit demographic data, NHLBI asthma severity classification, historical asthma severity risk factors, comorbidities, and secondary admission diagnoses.

Variable	Pediatric Floor ($n = 179$)	PICU ($n = 158$)	p Value
Age, *years* ± *SD*	8.7 ± 3.4	9.2 ± 3.4	.17
Gender ratio, *male:female*	1.4:1	1.4:1	>.99
Body mass index, kg/m^2 ± *SD*	18.8 ± 5.3	21.1 ± 13.5	.03
Weight, kg ± *SD*	37.2 ± 21.5	42.9 ± 24.3	.02
Racial background			
Asian, *n* (%)	13 (7%)	10 (6%)	.83
Black, *n* (%)	79 (44%)	84 (53%)	.1
Caucasian, *n* (%)	86 (48%)	62 (40%)	.12
Other, *n* (%)	1 (1%)	2 (1%)	.6
Hispanic, *n* (%)	20 (11%)	13 (8%)	.46
NHLBI asthma classification			
Intermittent, *n* (%)	67 (37%)	29 (18%)	<.01
Mild persistent, *n* (%)	42 (23%)	38 (24%)	.89
Moderate persistent, *n* (%)	59 (32%)	65 (41%)	.14
Severe persistent, *n* (%)	11 (6%)	26 (17%)	<.01
Asthma severity risk factors			
Hx of noncompliance, *n* (%)	26 (15%)	46 (29%)	<.01
Pre-admission pulmonologist, *n* (%)	43 (24%)	67 (42%)	<.01
Pet / animal exposure, *n* (%)	73 (41%)	59 (37%)	.57
Preventative omalizumab, *n* (%)	0 (0%)	3 (2%)	.1
Preventative steroid inhaler, *n* (%)	73 (41%)	102 (65%)	<.01
Previous intubation for asthma, *n* (%)	7 (4%)	8 (5%)	.79
Previous PICU admission, *n* (%)	34 (19%)	63 (40%)	<.01
Tobacco exposure, *n* (%)	90 (50%)	71 (45%)	.38
Comorbidities			
Allergic rhinitis, *n* (%)	92 (51%)	81 (51%)	>.99
Atopic dermatitis, *n* (%)	47 (26%)	38 (24%)	.71
Food / environmental allergy, *n* (%)	59 (33%)	73 (46%)	.01
Gastroesophageal reflux, *n* (%)	14 (8%)	11 (7%)	.83
Minor cardiac disease[a], *n* (%)	5 (3%)	7 (4%)	.55
Obesity, *n* (%)	28 (16%)	35 (22%)	.16
Prematurity, *n* (%)	17 (10%)	10 (6%)	.31
Seizure disorder, *n* (%)	19 (11%)	17 (11%)	.17
Sickle cell disease, *n* (%)	7 (4%)	10 (6%)	.33
2^o admission diagnoses			
Allergic reaction, *n* (%)	3 (2%)	0 (0%)	.25
Bacterial URI, *n* (%)	8 (4%)	6 (4%)	.79
Bacterial pneumonia, *n* (%)	14 (8%)	18 (11%)	.27
Cardiopulmonary arrest, *n* (%)	0 (0%)	1 (1%)	.46
Pneumothorax, *n* (%)	2 (1%)	3 (2%)	.66
Viral respiratory infection, *n* (%)	42 (23%)	53 (36%)	.05
Immunization status up to date, *n* (%)	142 (79%)	125 (79%)	>.99
Missing influenza vaccine, *n* (%)	62 (34%)	56 (35%)	.91
Preadmission PASS value, *median (IQR)*	6 (4-8)	11 (9-12)	<.01

NHLBI: National Heart, Lung and Blood Institute; PASS: pediatric asthma severity score; PICU: pediatric intensive care unit; *SD*: standard deviation; URI: upper respiratory infection.

[a]Minor cardiac disease were atrial septal defect, patent foramen ovale, or other noncritical congenital heart disease.

mean of 7.8 ± 12.7 h after transfer. Two of these readmissions (40%) were observed between 7 pm and 7 am. Children with PICU readmission were eventually transferred to a lower level of care and discharged from the general pediatric floor. Upon PICU readmission, three were placed on NIV, one received terbutaline, and one inhaled heliox therapy. Children with and without PICU readmission did not differ with respect to mean age (8.4 ± 4.3 vs. 9.1 ± 3.3 years, $p = .63$), weight (35 ± 15.9 vs. 42.5 ± 24.3 kg, $p = .49$), gender ratio (1.4:1 vs. 0.7:1, $p = .65$), NHLBI asthma severity classifications, historical asthma severity risk factors, comorbidities, secondary hospital diagnoses, or median duration of PICU LOS after discontinuation of continuous albuterol or other PICU-level interventions (11.7 [IQR: 10.2–12.3] vs. 10.1 [IQR: 5.8–16.1] hours, $p = .73$). Children with PICU readmissions had greater incidence of NIV use (60% vs. 14%, $p = .02$), hospital LOS (7.3 ± 2.9 vs. 3.9 ± 1.8, $p < .01$), and proportion of patients that receiving oxygen supplementation at time of transfer to a lower level of care (60% vs. 16%, $p = .03$) compared to those transferred without a PICU readmission.

Median PASS values preceding transfer to a lower level of care from the PICU were not different than those with and without PICU readmissions (6 [IQR: 5–7] vs. 4 [IQR: 3–5], $p = .07$). Unadjusted logistic regression of PASS preceding transfer to a lower level of care on PICU readmission yielded an odds ratio of 1.6 (95% CI: 0.97–2.7, $p = .06$).

Table 3. Medication administration, respiratory interventions, and general hospital outcomes for the study sample, general pediatric floor, and pediatric intensive care unit cohorts.

Variable	Pediatric Floor ($n = 179$)	PICU ($n = 158$)	p Value
Length of stay			
Hospital, days ± *SD*	1.3 ± 0.8	2.6 ± 1.6	<.01
PICU, days ± *SD*	n/a	1.3 ± 1	n/a
Post-PICU, days ± *SD*	n/a	1.4 ± 1.2	n/a
Medications administered			
Aminophylline, *n* (%)	n/a	0 (0%)	n/a
Continuous albuterol, *n* (%)	n/a	140 (89%)	n/a
Heliox, *n* (%)	n/a	7 (4%)	n/a
Ipratropium, *n* (%)	165 (92%)	149 (94%)	0.51
Ketamine, *n* (%)	n/a	8 (5%)	n/a
Magnesium sulfate, *n* (%)	62 (35%)	136 (86%)	<.01
Montelukast, *n* (%)	39 (22%)	49 (31%)	.06
Subcutaneous epinephrine, *n* (%)	2 (1%)	12 (8%)	<.01
Terbutaline, *n* (%)	n/a	14 (9%)	n/a
Received antimicrobials, *n* (%)	24 (13%)	25 (16%)	.54
Respiratory care interventions			
Regular nasal cannula, *n* (%)	64 (36%)	73 (46%)	.06
Oxy-mask, *n* (%)	31 (17%)	111 (70%)	<.01
Bilevel positive airway pressure, *n* (%)	n/a	9 (6%)	n/a
High-flow nasal cannula, *n* (%)	n/a	15 (9%)	n/a
Any noninvasive ventilation, *n* (%)	n/a	24 (15%)	n/a
Mechanical ventilation, *n* (%)	n/a	9 (6%)	n/a
Extracorporeal life support, *n* (%)	0 (0%)	0 (0%)	>.99
Hospital mortality, *n* (%)	0 (0%)	0 (0%)	>.99
Unplanned hospital readmission			
Within 7 days, *n* (%)	3 (2%)	1 (<1%)	.62
Within 30 days, *n* (%)	5 (3%)	4 (3%)	>.99

PICU: pediatric intensive care unit; *SD*: standard deviation.

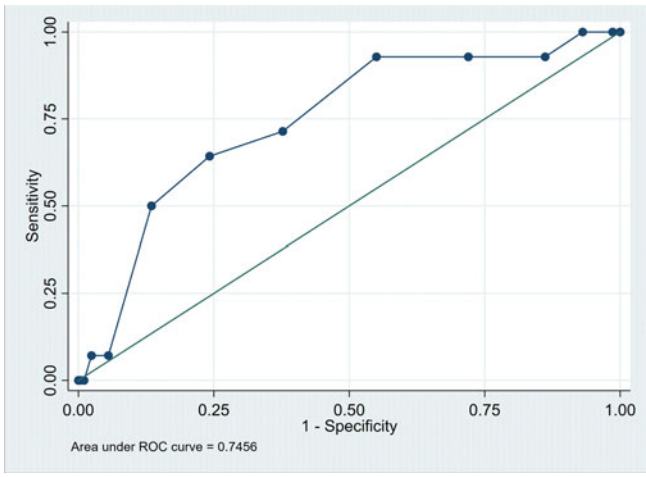

Figure 2. Receiver operator characteristic curve of PASS immediately preceding either admission from the ED to the general pediatric floor or PICU to de-escalation to the general pediatric floor on the incidence of study composite outcome (combined frequency of late-rescue and <24-h PICU readmission).

Unplanned hospital readmission data

Of the 328 children studied, nine unplanned, same-cause readmissions within 30-days of hospital discharge were noted. Children with hospital readmission had greater mean age (11.8 ± 3.1 vs. 8.9 ± 3.4 years, $p = .01$), weight (57 ± 21.9 vs. 39.2 ± 22.6 kg, $p = .02$), NHLBI classification of moderate to severe persistent asthma (89% vs. 47%, $p = .01$), history of previous intubation and mechanical ventilation (33% vs. 4%, $p < .01$), and history of prematurity (55% vs. 7%, $p < .01$). No other differences were observed for historical and index admission variables including mechanical ventilation, NIV, medications applied, or presence of discharge pulmonary follow up. Median PASS preceding hospital discharge were generally low at 2 (IQR: 1–3) and less in children with unplanned hospital readmission (1 [IQR: 1–1] vs. 2 [IQR: 1–3], $p = .02$). ROC curve analysis of PASS preceding hospital discharge on incidence of same-cause, unplanned hospital readmission yielded low discriminative data with an AUC of 0.28 (95% CI: 0.11–0.44).

Discussion

In this retrospective, descriptive cohort study of 328 children admitted to the general pediatric unit and PICU for acute asthma exacerbation, a PASS threshold value of nine identified most children admitted to our facility for asthma who subsequently required an escalation of inpatient services to the PICU within 24 h of transfer or admission to the general pediatric unit. While PASS may assist in the selection of appropriate inpatient unit admission, PASS values prior to discharge were not discriminatory for index hospital readmission. Our data represent one of the first assessments of clinical outcome validity for PASS and may assist intensivists, hospitalists, and emergency department providers in the selection of suitable inpatient level of care and reduce the inpatient disposition errors.

Determining appropriate inpatient level of care (general pediatric unit vs. PICU) is multifactorial and necessitates an understanding of the expected clinical trajectory of disease pathophysiology, the characteristics and comorbidities unique to that individual patient, and the therapeutic resources and clinical capacities that vary between hospital units, institutions, and regional standards of care. In some centers, children are admitted to a higher level of care, monitored until assurance of improving clinical status, and de-escalated to the general pediatric until hospital discharge. A PICU admission allows for closer monitoring, skilled nursing, expert respiratory care, and subspecialty oversight. However, PICU beds are a limited and expensive resource. Identifying objective metrics to reduce or eliminate an urgent, unplanned PICU admission is, therefore, essential to clinical providers throughout the hospital system.

The unplanned escalation of care from the general pediatric unit to the PICU after admission from the ED should not be considered an anticipated trajectory for a percentage of children with status asthmaticus, but rather a potentially avoidable event that could result in patient harm. While none of the patients escalated to the PICU in our sample required invasive ventilation, several required NIV and adjunctive asthma therapies. Unplanned transitions in care, such as late-rescues and PICU readmissions, necessitate appropriate handover between providers and the physical relocation of the patient that have been associated with 80% of in-hospital sentinel events, therapeutic errors, inappropriate testing, increased hospital costs, and prolonged LOS (20–24). An increased LOS results in excessive costs and resource utilization leading to potentially avoidable exposure to healthcare-acquired conditions, serious safety events, and patient complications. Additionally, unplanned escalations results in patient anxiety and parental stress undermining a therapeutic trust between providers, the patient, and their family (25,26).

Standardized decision-making protocols for disposition of patients with status asthmaticus have been shown to decrease hospital LOS, utilization of PICU-level resources, and duration of continuous nebulized albuterol treatments (27). In our institution, PASS data are assigned to assess disease severity and suggest clinical trajectory, but not used to determine decisions about clinical treatment or disposition. We found PASS to be associated with late-rescues and PICU readmissions within 24-h. If the threshold PASS value identified in our study was selected to determine an upper limit for general ward admission, half of unplanned events would have been prevented. However, unplanned PICU admissions would not be eliminated. Using the same threshold, seven children (4%) would have been admitted to the PICU that did not require a higher level of care. Thus, PASS could provide additional discriminatory power to identify at risk children for unplanned readmission, but at the expense of yielding conservative, unnecessary PICU admissions.

Unlike determining appropriate inpatient level of care, an assessment of suitability for hospital discharge without readmission encompasses several factors unrelated to discharge physical exam or severity of illness metrics. Several historical, demographic, and clinical characteristics have been identified as risk factors for frequent, unplanned hospital readmissions in children with status asthmaticus (1–6) including obesity, chronic severity of illness/degree of asthma control (e.g. NHLBI classification), presence of an asthma medical home, race, history of previous PICU admission, and history of asthma requiring mechanical ventilation. We noted similar disparities among children in our study with and without unplanned hospital readmission such as greater NHLBI asthma classification severity, history of previous intubation and mechanical ventilation, and comorbid prematurity (gestational age <34 weeks). Therefore, it is not surprising that PASS preceding discharge did not discriminate unplanned hospital readmission within 30-days. We conclude that PASS may be more suited for acute, inpatient stratification rather than a predictor of the patient's chronic medical course. This emphasizes the importance of follow up with a pulmonologist and the need for a pulmonary medical home in this population.

Limitations

A retrospective methodology was chosen for feasibility as late rescues and PICU readmissions are historically rare outcomes. This methodology may result in sampling bias due to inaccurate or incomplete documentation. Hospital asthma protocols and respiratory scoring may vary across and within institutions limiting the generalizability of our data. Careful attention to our study sample, local institutional resources, clinical unit capacities, and regional standards must be considered prior to adoption of PASS and modification of admission practices. Still, our findings likely represent similar experiences at other tertiary pediatric referral centers in the United States compared to smaller community based PICUs with varying resources. During the study period, our institution did not have an intermediate care or progressive care unit. These data cannot be generalized to institutions where children with status asthmaticus are triaged into those units. The primary outcome was a composite and while late rescues and PICU readmissions are similar (both represent escalation of care to the PICU from the general pediatric unit), they may represent different phases of illness ("ramp up" vs. "ramp down"). Other investigations have defined late-rescues in shorter intervals (within 6 or 12 h). In our sample, all late-rescues and most of the 24-h readmissions would fit under the within 12-h definition. Recognizing potential limitations in general pediatric unit respiratory assessments, we selected a 24-h definition to capture children with delayed or unrecognized deterioration. Other pediatric asthma scoring metrics have been developed (e.g. Pediatric Respiratory Assessment Measure) and our study findings cannot be applied to these metrics without further study. Investigations to determine superiority among various asthma and respiratory severity scoring metrics suggest inadequate clinical validity, rater reliability, and generalizability for most existing severity scores in children (12,13). However, PASS appears to be the most clinically studied and validated metric currently. PASS data were documented and available in the medical record for review by providers from the ED, general pediatric ward, and PICU. While knowledge of scores may have influenced decision making regarding disposition, PASS were not used as admission or transfer criteria in our institution during this study period.

Conclusions

A PASS $\geq$ 9 preceding hospital admission from the ED or transfer to a lower inpatient level of care from after PICU admission identifies children with status asthmaticus who are at highest risk for subsequent deterioration and escalation of inpatient level of care. Prior to hospital discharge, PASS does not discriminate chronic disposition success (i.e. hospital discharge without 30-day unplanned readmission). We conclude that PASS may assist providers in acute inpatient disposition decision-making but is unlikely to add value as part of hospital discharge criteria.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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