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Impact of prehospital pediatric asthma management protocol adherence on clinical outcomes

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ABSTRACT

Objective: To evaluate the frequency of EMS protocol non-adherence during pediatric asthma encounters and its association with emergency department (ED) length of stay (LOS) and hospital admission.

Methods: This is a retrospective review of asthma encounters aged 2–17 years transported by EMS to a pediatric ED from 2012 to 2017. Our primary outcome was hospital admission based on prehospital protocol adherence defined as: (1) bronchodilator administration, (2) treatment of hypoxia with oxygen, or (3) administration of intramuscular (IM) epinephrine in encounters with high severity of distress. Multivariable logistic regression estimated the association between protocol non-adherence and hospital admission.

Results: During the study period, 290 EMS encounters met inclusion criteria. Median age was 9 years (IQR 5–12), 63% were male, 40% had moderate to severe exacerbations, and 24% were admitted. Protocol non-adherence occurred in 32% of encounters with failure to administer bronchodilators in 27% and failure to administer IM epinephrine when indicated in 83%. Prehospital steroids were administered in 8% of encounters. After adjusting for covariates, protocol non-adherence was not statistically associated with likelihood of inpatient admission (OR 1.3; 95% CI: 0.6–2.6).

Conclusions: Among prehospital pediatric asthma encounters, EMS protocol non-adherence is common but not associated with a higher frequency of hospital admission. Hospital admission was associated with acute exacerbation severity suggesting further research is needed to develop a valid prehospital asthma severity assessment scoring tool.

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Introduction

Asthma is among the most common chronic conditions of childhood, affecting 7.5% of children (1). Patients with asthma frequently require emergency care for their acute exacerbations in both the Emergency Department (ED) and from Emergency Medical Services (EMS). Although pediatric patients constitute a small proportion of EMS transports (2,3), respiratory distress is one of the most common complaints, comprising 10–15% of all pediatric EMS transports (4–6).

To date there is limited research into EMS provider (pre-hospital) management of pediatric asthma patients. Among existing studies of prehospital management of acute asthma exacerbations in children, medication errors and protocol non-adherence are common (7,8). Few studies have examined the effect of EMS asthma treatment on ED or hospital outcomes (8–12). Of these studies, results have been mixed. One study showed no difference in hospital admission rates between patients treated Albuterol vs Terbutaline by EMS

(11), and other studies suggesting steroid administration by EMS decreases hospital admission rates (10,12).

Our lack of understanding about the impact of prehospital management on patient outcomes in pediatric asthma is a significant gap in this body of research. This study aims to describe the frequency of EMS protocol non-adherence in the management of pediatric acute asthma exacerbations and determine the impact of protocol non-adherence on hospital outcomes. We hypothesized that prehospital protocol non-adherence in the management of pediatric acute asthma exacerbations would be associated with increased rates of hospital admission.

Methods

Study design

This was a retrospective cohort study of ED visits where patients aged 2 to ≤ 17 years of age were transported from

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the scene by EMS to a tertiary-care pediatric hospital for an acute asthma exacerbation during a six-year study period (2012 through 2017). This study was approved by the institution's local institutional review board.

Study setting and population

This study was conducted at a large regional free-standing children's hospital that serves as a tertiary care Level 1 American College of Surgeons verified Trauma Center with an ED annual census of approximately 80 000 patients per year. The ED receives over 5,500 EMS transports and manages approximately 1,500 patients with moderate to severe asthma exacerbations annually.

The study population were children age 2 to ≤ 17 years of age with an ED diagnosis of an asthma exacerbation or wheeze based on ICD-10 (*International Classification of Disease, Version 10*) or ICD-9 (*Version 9*) codes and an established diagnosis of asthma defined as prior diagnosis of asthma or wheezing in the electronic health record (EHR) who were transported from the scene by a diverse group of scene response EMS agencies serving a large metropolitan area population of over 2 million people. Encounters for children with the following were excluded: wheeze not due to an asthma exacerbation, co-morbid illness interfering with or contraindicating usual asthma therapy (e.g., facial or airway abnormalities, tracheostomy or mechanical ventilation dependence, chronic lung disease, congenital heart disease, cystic fibrosis, pneumothorax, croup), or if the EMS patient care report (PCR) was not available.

Data collection

We queried our institutional EHR, EpicCare® (EpicCare, Veroni, WI), a computerized patient tracking and charting system, for eligible patient encounters. We subsequently reviewed these encounters to ensure they met inclusion criteria. From our eligible patient encounters, we assembled a secondary analytic dataset by manual chart review. In EpicCare®, all events including arrival, discharge, asthma score assessment, and medication administration are automatically time stamped. EpicCare® also has a repository of external documents accessible in a patient's medical record. External EMS PCRs are available in approximately 90% of patient encounters. We extracted data on all interventions from the time-stamped flowsheets within the hospital EHR and EMS PCR when available. Data elements not available in the time-stamped flowsheets were extracted from narrative notes in either system.

We collected and managed study data using REDCap (Research Electronic Data Capture), a secure, web-based electronic data capture tool hosted at the study institution

(13). All data were imported into SAS Version 9.4 (SAS Institute Inc., Cary, NC) for analysis.

Variables and measurements

We collected data on patient demographics including asthma severity (see definition below), EMS management (i.e., prehospital provider primary impression and respiratory assessment, encounter time, transport priority, and treatments and interventions administered), and hospital course (i.e., serial acute exacerbation severity classifications as defined by the Pulmonary Asthma Score [PAS] (14–16), treatments administered, disposition, and ED and inpatient LOS).

Baseline asthma severity assessment

For the purpose of this study, we defined baseline asthma severity as intermittent or persistent according to the National Heart Lung and Blood Institute (NHLBI) classification system (17). We determined the patient's asthma severity classification via the EHR from subspecialty, admission, primary care, or ED documentation utilizing a pre-established source hierarchy. For encounters where asthma classification was not explicitly documented in the EHR, we defined persistent as patients on an asthma controller medication (including inhaled corticosteroid, long-acting beta2-agonist, or leukotriene receptor antagonist) and all other patients were classified as "unknown." Three study investigators independently reviewed 20 randomly selected charts using the source hierarchy to assess interrater reliability. Study investigators agreed on the determination of asthma severity as either intermittent or persistent in 86.7% of charts reviewed; Fleiss' Kappa was 0.67 (95% Confidence Interval (CI) = 0.43–0.91), indicating substantial agreement (18).

Acute asthma exacerbation severity assessment

Given the lack of an objective and validated measure of acute asthma exacerbation severity in the out-of-hospital setting, we utilized the PAS on ED arrival to classify the patient's acute asthma exacerbation severity. The PAS is a 5–15 point scale based on assessment of respiratory rate, oxygen requirements, auscultation, retractions, and dyspnea (14), which is assigned to patients by a trained respiratory therapist, and is the standard score utilized at the institution where this study was conducted. The PAS categorizes acute asthma exacerbation severity into three categories: mild (PAS ≤ 7), moderate (PAS 8–11), or severe (PAS 12–15). These severity classifications guide management according to a clinical treatment pathway at the study institution.

Determination of EMS protocol adherence

For the purposes of this study, we utilized the 2019 regional district EMS protocol for pediatric wheezing (Figure 1), which serves as standard of care to define protocol adherence. This protocol is reviewed and approved annually by

regional EMS medical directors. Pediatric EMS protocols are designed for patients ≤ 12 years, but the initial management does not differ from the adult asthma protocol. Thus, the pediatric EMS asthma protocol was applied to all pediatric patients from 2–17 years old included in our

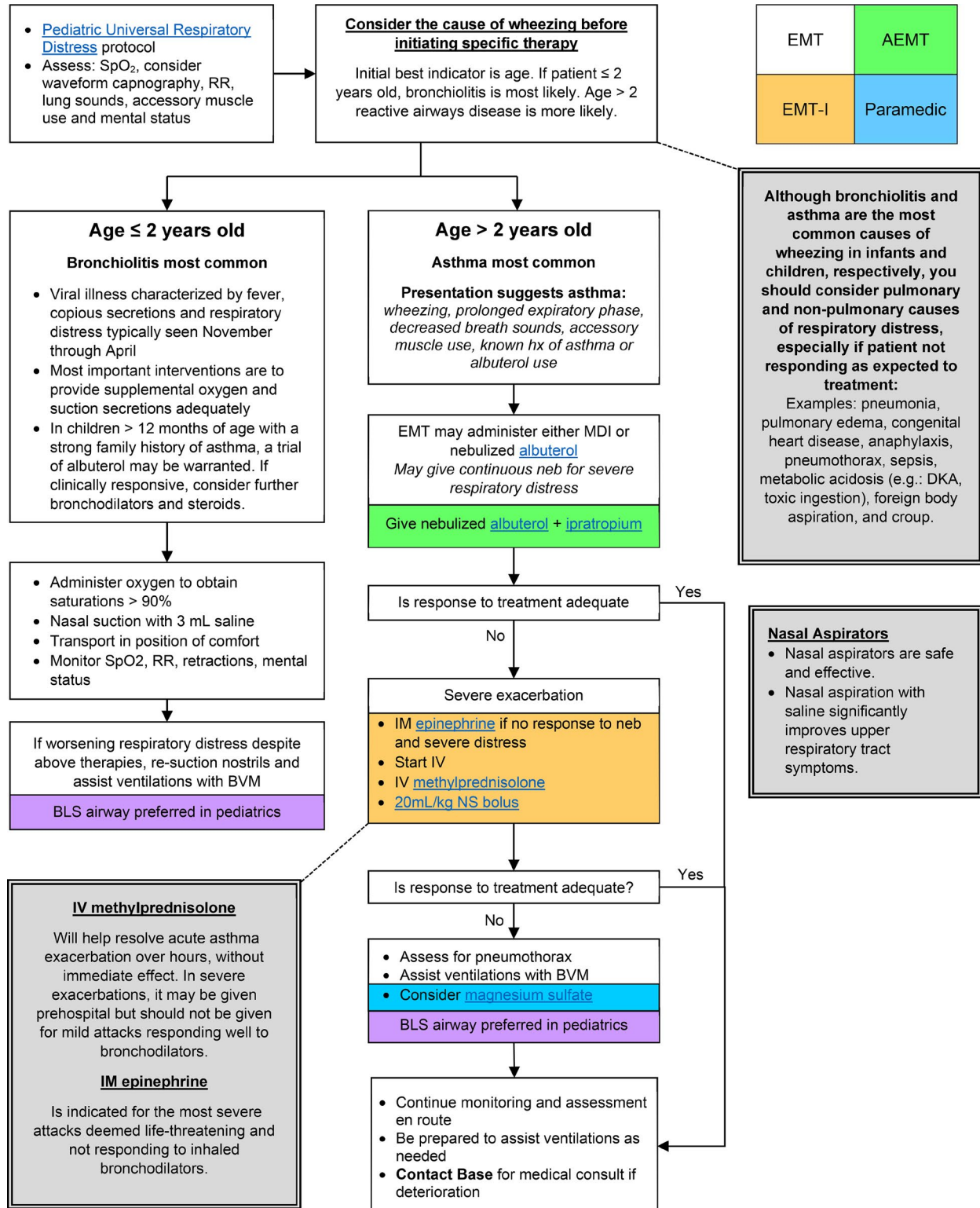


Figure 1. Regional district emergency medical services protocol for pediatric wheezing.

study. We used initial PAS on presentation to the ED as a proxy for acute asthma exacerbation severity in the field, using the PAS categorization of mild, moderate, or severe.

According to the EMS protocol, initial treatment for acute asthma exacerbations across all severities consists of inhaled albuterol and ipratropium bromide. Treatment of “severe” attacks that do not respond to inhaled bronchodilators includes intramuscular (IM) epinephrine and subsequently intravenous (IV) methylprednisolone if there is no improvement in respiratory status. Administration of oxygen is overall standard of care for patients with oxygen saturations $< 90\%$ in room air and therefore was considered an essential aspect of protocol adherence. We defined administration of oxygen as use of nasal cannula, blow-by oxygen, non-rebreather mask or administration of any nebulized medication.

We defined EMS protocol adherence as: 1) For all patients: any administration of a bronchodilator (albuterol/ipratropium bromide); 2) For patients whose presentation was severe (ED arrival PAS 12–15): administration of IM epinephrine, and 3) For patients with hypoxia (Oxygen saturation $< 90\%$ documented by EMS): administration of oxygen (in any form). Protocol adherence did not include prehospital corticosteroid administration as the regional EMS protocol only specifies corticosteroid administration when there is no improvement after IM Epinephrine.

Outcome measures

The primary outcome measure was the difference in the proportion of patient encounters resulting in hospital admission (admitted to inpatient unit vs. discharged home from the ED) between those managed according to EMS protocol and those who were not. We stratified the primary outcome by the three classifications of acute asthma exacerbation severity based on the PAS (mild, moderate, or severe).

Secondary outcome measures included the association between protocol adherence and ED LOS (hours) and hospital LOS (days). As all events in the EHR are timestamped, we defined ED LOS as the time from arrival to the ED by EMS to the time of discharge or admission to the inpatient unit and hospital LOS as the time of admission to the time of discharge to home. We also assessed EMS contact time (time of arrival at the scene to time of arrival to the hospital), prehospital steroid administration, and additional ED interventions including type of oxygen administration, additional asthma therapies (i.e., continuous albuterol and IV Magnesium), and if IV access was obtained.

Data analysis

Univariable analysis was used to generate descriptive statistics. We compared demographics, EMS interventions,

presenting ED vitals, ED interventions, and outcomes among encounters with EMS protocol adherence to those encounters without using chi-square and Fisher's exact tests for categorical variables and t-tests and Wilcoxon Mann Whitney tests for continuous variables. The data were evaluated at a visit level, with some patients having more than one visit. For our primary outcome, hospital admission, we calculated frequencies and proportions with 95% confidence intervals. Multivariable logistic regression was performed to identify independent predictors of hospital admission. Covariates from the univariable analysis, where $p < 0.2$, were entered into the logistic regression model and remained in the model if $p < 0.1$, using backward selection. The covariates that met the initial model inclusion criteria were age, race, EMS documentation of labored breathing, EMS steroid administration, asthma exacerbation severity (mild, moderate, severe) and protocol adherence. Covariates that remained in the multivariable analysis after backward selection were asthma exacerbation severity and protocol adherence; we forced EMS protocol adherence to stay in the model, as it was the main covariate of interest. Multivariable logistic regression results are presented as adjusted odds ratios and 95% confidence intervals. Statistical significance was set at $p < 0.05$.

Demographics and outcomes for encounters missing an ED PAS were analyzed and compared to the patients with a PAS. We performed a sensitivity analysis to determine how the results would change when considering our missing data. To do the sensitivity analysis, we compared the patient demographics and outcomes when the patients with a missing PAS were grouped with the mild acute asthma exacerbation category versus leaving the patients with a missing PAS as their own category.

Results

Demographics

A total of 795 patient encounters were identified in the EHR query, of which 63.5% were excluded ([Figure 2](#)). The most common reason for exclusion was interfacility transfer, defined as transport from a different health-care facility (outpatient clinic, different hospital inpatient unit or ED). A total of 54 (10.7%) patient encounters were excluded because the EMS PCR was not available for review. For encounters excluded because no EMS PCR was available, there was no difference in age or sex in comparison to those encounters that were in the analytic cohort. However, a higher proportion of excluded patients were Caucasian and they were more likely to have intermittent asthma.

During the study period, EMS transported 226 patients in 290 separate encounters that met inclusion criteria. For the 42 patients with multiple EMS encounters during the

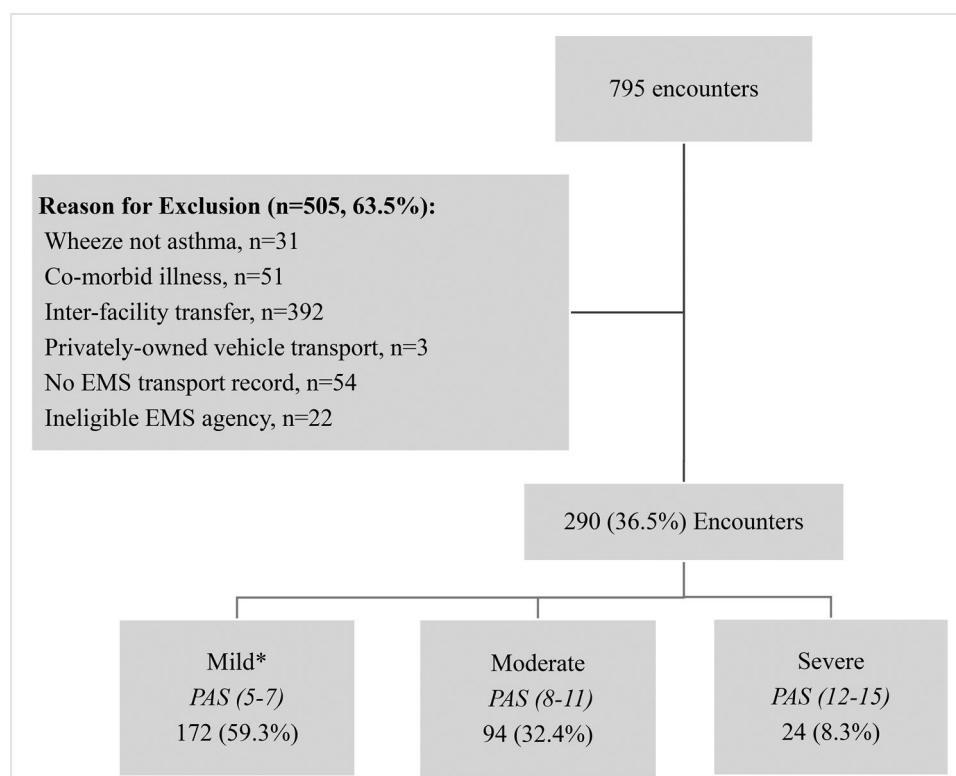


Figure 2. Study population derivation.

study period, the median number of encounters was 2 (IQR 2, 3) and median time between encounters was 5 (IQR 3, 12) months. Seventy-two (24.8%) encounters were missing a PAS. These patients were less likely to receive steroids in the ED and had a shorter LOS reflective of a mild acute asthma exacerbation. Therefore, we report the results of our outcomes with those missing a PAS grouped with those who had a mild acute asthma exacerbation (PAS 5–7), now referred to as "mild." See [Supplemental Table A.1](#) for an analysis of these groups separated. Overall, median age was 9 years (IQR 5,12), 63.1% were male, 28.5% were Hispanic, 76.6% had persistent asthma, and 23.8% required hospital admission (13.0% of whom required ICU admission) ([Table 1](#)). Presenting PAS among encounters were Mild (59.3%), Moderate (32.4%), or Severe (8.3%).

Among the cohort of patient encounters, EMS primary impression was most commonly dyspnea (45.2%) followed by asthma (28.3%) and respiratory distress (18.7%). EMS documented the presence of labored breathing in 127 encounters (43.8%). Overall, 8.2% ($n = 24$) of the encounters had a primary impression that was not related to asthma or respiratory distress ([Supplemental Table A.2](#)).

EMS interventions by acute asthma severity

EMS interventions stratified by PAS are shown in [Table 2](#). Patient encounters with higher severity distress had a

measurably lower EMS contact time, however, there was no difference in the overall documentation of labored breathing by EMS. EMS administered bronchodilators to the majority of patients with no difference based on severity of presentation, yet, only 16.7% of those with a severe presentation (PAS >12) received IM Epinephrine. Intravenous access was obtained in 21.0% ($n = 61$), however corticosteroids were only given to 7.6% ($n = 22$) and IV Magnesium Sulfate was not administered during any of the encounters. Overall, protocol adherence occurred in 68.3% of encounters. Reasons for non-adherence in our study population include a failure to administer bronchodilators in 26.9% and failure to administer IM Epinephrine in 83.3% of patients with a severe presentation. All hypoxic patients were treated with oxygen.

EMS protocol adherence and patient outcomes

Overall, the proportion of encounters requiring hospital admission was significantly higher when EMS care did not adhere to the protocol compared to encounters when the protocol was followed (32.6% [95% CI = 23.0–42.2%] vs 19.7% [95% CI = 14.2–25.2%], $p = 0.02$). In addition, unadjusted, EMS protocol non-adherence significantly increased the odds of a hospital admission (OR = 1.97 [95% CI = 1.13–3.45]). However, after adjusting for covariates, the association between EMS protocol non-adherence

Table 1. Demographics of patient encounters stratified by pulmonary asthma score.

Demographics and Outcomes, n (%)	Mild, PAS 5–7 (n = 172)	Moderate, PAS 8–11 (n = 94)	Severe, PAS 12–15 (n = 24)	p-value
Median age, years (IQR)	9 (6–12.5)	9 (5–12)	6 (4.5–12.5)	0.36
Male	101 (58.7%)	65 (69.2%)	17 (70.8%)	0.17
Insurance type				0.37
Public	148 (86.0%)	77 (81.9%)	20 (83.3%)	
Private	18 (10.5%)	16 (17.0%)	3 (12.5%)	
None	6 (3.5%)	1 (1.1%)	1 (4.2%)	
Race				0.34
White	44 (25.6%)	18 (19.2%)	3 (12.5%)	
Black	90 (52.3%)	57 (60.6%)	12 (50.0%)	
Native American	2 (1.2%)	1 (1.1%)	0 (0%)	
Multiple Races	11 (6.4%)	6 (6.4%)	5 (20.8%)	
Other	25 (14.5%)	12 (12.8%)	4 (16.7%)	
Ethnicity*				0.16
Non Hispanic	116 (67.4%)	73 (78.5%)	17 (73.9%)	
Hispanic/Latino	56 (32.6%)	20 (21.5%)	6 (26.1%)	
Asthma type				0.75
Intermittent	23 (13.4%)	11 (11.7%)	2 (8.3%)	
Persistent	127 (73.8%)	74 (78.7%)	21 (87.5%)	
Unknown	22 (12.8%)	9 (9.6%)	1 (4.2%)	
Presenting ED Vital Signs				
Pulse, mean (SD)	114 (23)	129 (25)	135 (21)	<0.001
Systolic BP, mean (SD)	117 (12)	115 (13)	116 (18)	0.73
Respiratory rate, median (IQR)	24 (20–28)	30 (24–38)	40 (31–46)	<0.001
Pulse Oximetry, median (IQR)	96 (95–98)	95 (93–98)	93.5 (91–96)	0.01

*Missing data: ethnicity (n = 2).

IQR = Interquartile Range; SD = Standard Deviation; BP = Blood Pressure; GCS = Glasgow Coma Scale; PAS = Pulmonary Asthma Score.

Table 2. EMS interventions for pediatric asthma encounters stratified by pulmonary asthma score.

EMS Interventions, n (%)	Mild, PAS 5–7 (n = 172)	Moderate, PAS 8–11 (n = 94)	Severe, PAS 12–15 (n = 24)	p-value
EMS Contact Time, median, minutes (IQR)*	25 (18–32)	22 (16–29)	21 (18–26)	0.01
EMS documentation of labored breathing	67 (39.0%)	47 (50.0%)	13 (54.2%)	0.25
EMS Medications Administered:				
Received Albuterol	125 (72.7%)	69 (73.4%)	18 (75.0%)	0.97
Number of Albuterol Doses				0.054
1	87 (70.2%)	44 (64.7%)	14 (77.8%)	
2	32 (25.8%)	22 (32.4%)	1 (5.6%)	
>3	5 (4.0%)	2 (2.9%)	3 (16.7%)	
Received Ipratropium	65 (37.8%)	40 (42.6%)	14 (58.3%)	0.15
Number of Ipratropium Doses				>0.99
1	64 (98.5%)	39 (97.5%)	14 (100%)	
2	1 (1.5%)	1 (2.5%)	0 (0%)	
Received IV Corticosteroid	11 (6.4%)	8 (8.5%)	3 (12.5%)	0.52
EMS Oxygen Administered	94 (54.7%)	50 (53.2%)	13 (54.2%)	0.97
EMS Placed IV catheter	34 (19.8%)	23 (24.5%)	4 (16.7%)	0.57
EMS Protocol Non-adherence	47 (27.3%)	25 (26.6%)	20 (83.3%)	<0.001
No bronchodilator administration	47 (27.3%)	25 (26.6%)	6 (25.0%)	
No IM Epinephrine in severe distress	n/a	n/a	20 (83.3%)	
No oxygen for pulse oximetry <90%	0%	0%	0%	

*Contact time = EMS arrival to hospital arrival, missing data n = 17.

EMS = Emergency Medical Services; IQR = Interquartile Range; IV = Intravenous; IM = Intramuscular; PAS = Pulmonary Asthma Score.

and hospital admission dissipates and is no longer significant; worse severity of presentation (i.e., higher PAS) is the only covariate significantly associated with hospital admission (Table 3).

ED LOS, hospital LOS, and further ED medical management of acute asthma exacerbations (including corticosteroid and IV magnesium administration) were not significantly different between encounters with EMS

Table 3. Multivariate analysis of odds of hospitalization for pediatric asthma encounters transported by EMS.

Covariate*	Adjusted Odds Ratio [†] (95% CI)
EMS Protocol Non-Adherence	1.28 (0.64–2.55)
Severity[‡]	
Moderate	7.70 (3.88–15.29)
Severe	24.09 (8.06–71.95)

*Covariates in initial model: age, race, documentation of labored breathing, EMS steroid administration, asthma exacerbation severity (mild, moderate, severe) and protocol adherence. Remaining covariates after backward selection: asthma exacerbation severity and protocol adherence.

[†]Reference group: Mild severity = Pulmonary Asthma score 5–7.

[‡]Moderate = Pulmonary Asthma Score 8–11; Severe = Pulmonary Asthma Score 12–15.

EMS = Emergency Medical Services; CI = Confidence Interval.

protocol adherence and those with protocol non-adherence. In contrast to EMS interventions (Table 2), corticosteroids were given in the ED in >75% of cases and occurred in similar proportions of patients with protocol adherence and protocol non-adherence (77.3% vs 71.7%, $p=0.31$). Among the 24 encounters for a severe exacerbation, 17 (70.8%) were admitted. Those patients with a PAS ≥ 12 who received pre-hospital IM Epinephrine had a significantly shorter ED LOS (2.6 vs 6.6 h, $p=0.01$) prior to admission.

Discussion

In this study of pediatric asthma encounters transported by EMS, we found no association between prehospital protocol non-adherence and hospital admission after adjusting for confounding variables. However, hospital admission does appear to be driven by acute asthma exacerbation severity. We did find a failure to treat according to protocol among the highest severities of acute asthma exacerbation, which highlights the need for accurate assessment of acute asthma exacerbation severity by EMS professionals.

Our study suggests that treatment of pediatric asthma patients with severe exacerbations according to EMS protocol in the prehospital setting may have positive effects on ED LOS. While appropriate prehospital administration of IM Epinephrine in children with severe exacerbations occurred infrequently, when administered appropriately it was associated with an expedited ED course in those children who required admission. This may have implications for other prehospital interventions not assessed in this study. Other studies have also demonstrated that EMS interventions are associated with ED and hospital outcomes. Nassif et al. (10) found that adherence to a change in protocol promoting use of oral steroids was associated with both a decrease in hospital length of stay and admission, as well as a reduction in admission to the intensive care unit for patients of higher exacerbation severity. The authors did note a relatively low uptake of the new treatment protocol by EMS personnel. In our study, we did not

find a reduction in hospital admission as this was confounded by asthma exacerbation severity.

Although corticosteroids are a mainstay of treatment for acute asthma exacerbations in the emergency department and ambulatory care settings, only 7.6% of encounters in our study received corticosteroids which is consistent with other studies of EMS management of pediatric asthma (10,19,20). In our study, prehospital corticosteroid administration was likely low because corticosteroid administration is located at the end of protocols (i.e., after IM Epinephrine administration), and therefore only indicated among those with a severe exacerbation. In addition, the EMS agencies included in this study only utilize IV Methylprednisolone which requires multiple steps including the successful placement of an IV, reconstitution in saline, and determination and administration of an appropriate volume for pediatric patients. We found that an IV was placed in 21% of all encounters, yet corticosteroids were only administered in 7.6%, and therefore, it is not clear that IV access alone was a true barrier to corticosteroid administration in our study. Previous research demonstrates that IV catheters are frequently placed in children during EMS encounters but not necessarily utilized (21). Ultimately, the option to administer corticosteroids orally in the prehospital setting may improve overall corticosteroid administration as was found in the study by Nassif et al. (10) where the relative increase in administration was 60%. Changes to regional protocols and robust education about these changes should be considered as we gain a better understanding of the impact of early interventions and prehospital protocol adherence on patient outcomes.

Similar to other studies, we found EMS administered albuterol in approximately 75% of the encounters and administered ipratropium bromide in approximately 40% (10,20). The failure to use albuterol in all patients is not clearly understood but may be related to barriers in recognizing the presentation as an acute asthma exacerbation. In our study, we found protocol non-adherence to be highest in the most severe patients. We also found that in almost 10% of encounters, the EMS primary impression was not related to asthma suggesting that appropriate recognition of the clinical condition may play a role. However, in a study by Ramgopal et al. (20), the patient population of interest was defined by EMS documentation of wheezing, yet only 65% of encounters received albuterol. This suggests that even when wheezing is noted on exam, it is not a necessarily a clinical finding that prompts EMS to administer a bronchodilator.

EMS professionals care for pediatric patients infrequently, and assessment of pediatric respiratory distress is nuanced. There are several asthma severity scoring tools currently in use in emergency departments that help guide management of patients (14,16,22). A feasible and valid

objective measure of acute exacerbation severity or validated prehospital scoring tool is needed to guide prehospital provider severity assessments and treatment decisions. Thus, further research is needed to create a valid and easy-to-use scoring tool for the prehospital setting.

Limitations

The major limitation is the retrospective nature of this study. Our study population was derived from an ED diagnosis of an acute asthma exacerbation and as such, may be subject to misclassification bias. PAS score at ED presentation was used as a proxy for exacerbation severity, but may not accurately capture the patients' initial presentation. PAS score was used because it was the most objective measure available in this retrospective dataset. There is some missing data such as PCRs (leading to exclusion of encounters and a smaller sample size) and encounters where PAS was not obtained or documented. We combined encounters missing a PAS with those scored as mild because the missing category was demographically similar and they were managed similarly to the mild group. Additionally, this is a single-center study which limits the generalizability of our findings. Finally, our sample size was limited by our study time-period, which was determined by a period in which there were no changes to the regional EMS or ED asthma protocols. We expect that having more encounters in the severe category would have helped to better elucidate the nuanced role of severity of presentation on EMS protocol non-adherence and hospital admission.

Conclusions

In this study of prehospital care of pediatric acute asthma exacerbations, we found that EMS protocol non-adherence is common. However, EMS protocol non-adherence was not associated with a higher frequency of hospital admission. The most important factor assessed in this study that appears to drive hospital admission is acute exacerbation severity. This suggests that further research is needed to develop a valid prehospital assessment scoring tool to accurately determine asthma exacerbation severity in the field.

Declarations of interest statement

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

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PREHOSPITAL PEDIATRIC ASTHMA MANAGEMENT

Supplemental Table A.1: EMS Interventions for Pediatric Asthma Encounters Stratified by Pulmonary Asthma Score Including Those With a Missing Score.

EMS Interventions, n (%)	Missing PAS (n=72)	Mild, PAS 5-7 (n=100)	Moderate, PAS 8-11 (n=94)	Severe, PAS 12-15 (n=24)	p- value
EMS Contact Time, median, minutes (IQR)*	25 (18-33)	25 (18-32)	22 (16-29)	21 (18-26)	0.03
EMS documentation of labored breathing	28 (38.9%)	39 (39.0%)	47 (50.0%)	13 (54.2%)	0.41
EMS Medications Administered:					
Received Albuterol	50 (69.4%)	75 (75.0%)	69 (73.4%)	18 (75.0%)	0.87
Total Albuterol Doses					0.13
1	35 (70.0%)	52 (70.0%)	44 (64.7%)	14 (77.8%)	
2	13 (26.0%)	19 (25.7%)	22 (32.4%)	1 (5.6%)	
≥3	2 (4.0%)	3 (4.1%)	2 (2.9%)	3 (16.7%)	
Received Ipratropium	30 (41.7%)	35 (35.0%)	40 (42.6%)	14 (58.3%)	0.21
Total Ipratropium Doses					>0.99
1	30 (100%)	34 (97.1%)	39 (97.5%)	14 (100%)	
2	0 (0%)	1 (2.9%)	1 (2.5%)	0 (0%)	
Received IV Corticosteroid	7 (9.7%)	4 (4.0%)	8 (8.5%)	3 (12.5%)	0.36
EMS Oxygen Administered	42 (58.3%)	52 (52.0%)	50 (53.2%)	13 (54.2%)	0.87
EMS Placed IV catheter	13 (18.1%)	21 (21.0%)	23 (24.5%)	4 (16.75)	0.72
EMS Protocol Non-adherence	22 (30.6%)	25 (25.0%)	25 (26.6%)	20 (83.3%)	<0.001
No bronchodilator administration	22 (30.6%)	25 (25.0%)	25 (26.6%)	6 (25.0%)	0.87
No IM Epinephrine in severe distress	n/a	n/a	n/a	20 (83.3%)	
No oxygen for pulse oximetry <90%	0%	0%	0%	0%	

*Contact time=EMS arrival to hospital arrival, missing data n=17;

EMS=Emergency Medical Services; IQR=Interquartile Range; IV=Intravenous; IM-Intramuscular; PAS=Pulmonary Asthma Score

PREHOSPITAL PEDIATRIC ASTHMA MANAGEMENT

Supplemental Table A.2: List of EMS Primary Impressions Documented in the Patient Care Report

Allergic Reaction
Apparent Life-Threatening Event
Anxiety
Back Pain
Breathing Problem
Bronchitis
Clear Lung Sounds
Difficulty Breathing
Dyspnea
Exacerbation of Preexisting Condition
Influenza
Nausea/Vomiting/Diarrhea
Not Documented
Pain-Flank
Respiratory Arrest
Altered LOC
Respiratory Distress
SOB/Dyspnea/Difficulty Breathing
Trauma
Wheezing