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Prehospital management of pediatric asthma patients in a large emergency medical services system

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Abstract

Background: Asthma is a common pediatric diagnosis for emergency medical services (EMS) transports, however there is a paucity of data on prehospital asthma management. The purpose of this study was to describe prehospital management of pediatric patients with suspected asthma exacerbation.

Methods: We conducted a retrospective review of electronic medical records from 24 ground EMS agencies in Southwestern Pennsylvania between 1 January 2014 to 31 December 2017. We identified patients 2 to 17 years with documented wheezing, excluding those with suspected anaphylaxis. Patients with documented respiratory distress were classified as severe asthma. We report descriptive statistics of demographics, vital signs, and management including administration of medications and performance of procedures.

Results: Of 19 246 pediatric transports, 1078 (5.6%) patients had wheezing. Of these, 532 (49%) met criteria for severe asthma. Patients with severe asthma were more likely to be adolescents compared to those with nonsevere asthma (49.6% vs 6%; $P < .001$). While rates of intravenous methylprednisolone administration were higher in patients with severe asthma (68/532, 12.8%) compared to those with nonsevere asthma (13/546, 2.4%; $P < .001$), overall use of steroids was low (7.5%). Other therapies provided included albuterol (n = 699, 64.8%), ipratropium bromide (n = 271, 25.1%), and oxygen (n = 280, 26.0%). One hundred eighty patients (16.7%) received a peripheral IV line. Two patients (0.4%) were given continuous positive airway pressure.

Conclusion: Approximately 6% of pediatric EMS transports are for asthma. Steroid usage was low in even those with severe asthma, representing an area of process improvement. These data provide a baseline to future research to identify interventions that may improve outcomes.

KEYWORDS

asthma, emergency medical services, EMS, prehospital, steroids

1 | INTRODUCTION

Asthma is the most common chronic respiratory disease in children.[1] Asthma affects approximately 25 million individuals in the United

Abbreviations: ALS, advanced life support; CPAP, continuous positive airway pressure; ED, emergency department; EMS, emergency medical services; IQR, interquartile range; NEMSIS, National Emergency Medical Services Information System; PIV, peripheral intravenous line.

States, including 6.5 million children 0 to 17 years of age.[2] Approximately 50% of pediatric patients with asthma have at least one exacerbation annually, making this condition a leading cause of childhood hospitalization and school absenteeism.[3-6] From an acute care perspective, pediatric asthma accounts for 1.8 million emergency department (ED) visits annually.[7] One in 20 patients with asthma requires hospitalization every year, and asthma is the most common diagnosis among pediatric high utilizers of the ED.[6,8]

Despite the major public health burden caused by asthma, there are a paucity of data regarding the management of asthma in the prehospital setting. Respiratory distress is one of the most common pediatric medical conditions encountered by emergency medical services (EMS) providers.[9,10] Approximately 3% of all transports by EMS in one multiagency pediatric study are given bronchodilator therapy.[10] However, protocols for the treatment of asthma exacerbations vary widely and may be inconsistently applied. One study in 1998 reported that only 25% of suspected patients with pediatric asthma received beta-agonists, and only 5% received steroids in the prehospital setting.[11] These findings contrast with a more recent evaluation of an urban EMS system showing that nearly 75% of pediatric patients received albuterol. Improved pediatric asthma management by EMS may decrease hospital admissions or decrease length of stays and improve pediatric morbidity from asthma related causes. A recent study from one EMS agency suggested that protocols allowing the use of dexamethasone carry promise in shortening hospitalizations for this condition.[12] In light of these gaps and missed opportunities in care, EMS management of asthma has been selected as an area of high-priority research by the pediatric emergency care applied research network.[13] A better description of the management of asthma in the prehospital setting may serve as the basis of future research, protocol development and quality improvement efforts.

In this study, we evaluate the treatment of pediatric asthma in a regional EMS system comprised of multiple agencies to describe interventions currently performed by EMS for management of pediatric asthma. In addition, we describe treatment of patients with pediatric asthma before EMS evaluation to identify high-risk groups. These findings may have significance in quality improvement, protocol development, and in facilitating potential prospective research.

2 | METHODS

2.1 | Study design and setting

We performed a retrospective review of ground EMS transports from a scene to a hospital by 24 urban, suburban, and rural EMS agencies in Southwestern Pennsylvania between 1 July 2015 and 1 July 2017. In Pennsylvania, management of asthma exacerbations, chronic obstructive pulmonary disease, and bronchospasm is guided by a single advanced life support (ALS) protocol (Figure 1). During the study time period, there were no changes to this protocol. We reviewed data collected from a common electronic patient care record by EMS agencies that have research data use agreements with the University of Pittsburgh Medical Center and University of Pittsburgh. Approval for this study was obtained from the University of Pittsburgh institutional review board with a waiver of informed consent.

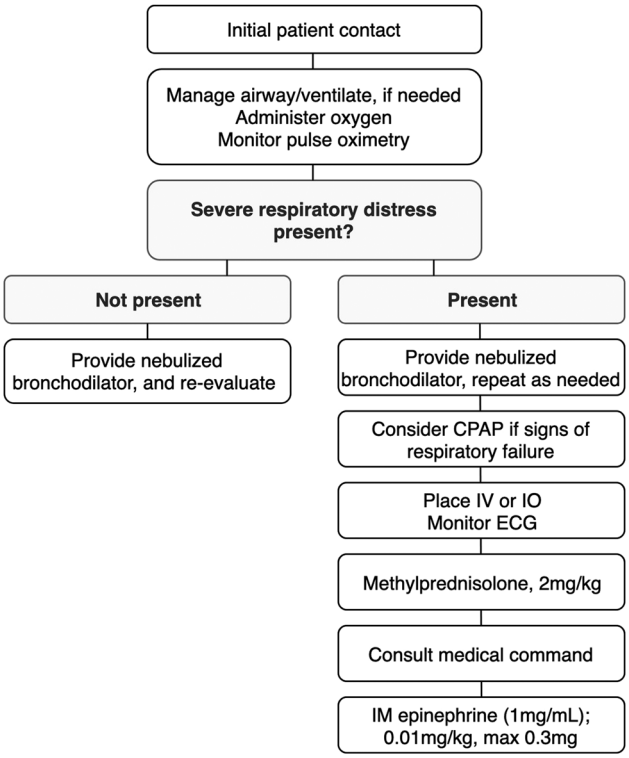

FIGURE 1 Summary of the Pennsylvania statewide advance life support protocol for asthma exacerbations as pertaining to pediatric patients. CPAP, continuous positive airway pressure; ECG, electrocardiogram; IV, intravenous line; IO, intraosseous line; IM, intramuscular

2.2 | Patient inclusion and data collection

Data were obtained from a National Emergency Medical Services Information System-compliant electronic prehospital medical record system (emsCharts, Warrendale, PA) used by all participating EMS agencies. Data were obtained from emsCharts in XML format and compiled into a research dataset using Matlab (MathWorks, Natick, MA) for extraction and Stata (StataCorp, College Station, Texas) for synthesis into a prehospital registry dataset. Patients were screened for potential inclusion in two ways: first, we identified patients by initial data search for patients who had documentation of "wheeze" in any part of the electronic medical record (EMR). Second, for those patients not identified in this manner but from whom the word "wheeze" and variants of this word was present in the EMS history and physical exam, two authors (SO, AM) manually reviewed the EMR to identify additional patients transported because of potential asthma exacerbation.

2.3 | Patient exclusion

Encounters for patients less than 2 years of age, more than 17 years of age, missing documented age, cardiac arrest, nontransports, scene assists, interfacility transports, encounters without a patient, and patients with medical category of allergy were excluded. We excluded patients more than 2 years of age as the etiology of wheezing at this age is more variable and more frequently due to bronchiolitis.[14] Cardiac arrest was defined as any of the following: (a) documented provider impression of cardiac arrest, death, traumatic arrest, or dead on arrival; (b) documented outcome listed as funeral home, pronounced, dead, or coroner transport; (c) documented rhythm of asystole, pulseless electrical activity, pulseless, agonal, or ventricular fibrillation; (d) documented procedure of defibrillation or cardiopulmonary resuscitation; or (e) documented use of epinephrine as dosed for cardiac arrest.

2.4 | Patient definitions

We classified patients into groups of nonsevere and severe asthma. Severe asthma was defined as any one of the following: agitated, fatigue, grunting, labored, nasal flaring, retractions, assisted, hypoxia, oxygen saturation less than 90%, and cyanosis.

2.5 | Measurements

From the study cohort, we abstracted patient demographics, transport characteristics, EMS vital signs (systolic blood pressure, heart rate, and respiratory rate, pulse oximetry), and lung sound assessment. Patient demographics included age, gender, race, ethnicity, weight, height, and medical complaint. Race was divided into categories of white, black, and other/unknown. Pediatric patients were further categorized as early childhood (2 to <6 years), middle childhood (6 to <12 years), and adolescent (12 to <18 years). Transport characteristics included year, season, time of day of transport, response time (between dispatch and arrival to scene), time at scene (between arrival to scene and departure to hospital), transport time (between departure from scene to arrival at hospital), provider certification (basic vs ALS), and use of cardiac monitor. We classified charted vital signs as abnormal or normal on the basis of Pediatric ALS guidelines.[15] From patients for whom a ZIP code was available at the scene, we abstracted median household income derived from the 2012 to 2016 American Community Survey 5-year estimates.[16] Income data were divided into four categories based on quartile.

2.6 | Outcomes of interest

Our primary outcomes were interventions for pediatric asthma management. The asthma medication interventions evaluated in the study were inhaled medications (albuterol, ipratropium only, and oxygen) alone or as in combination formulations, intravenous medications (steroids as methylprednisolone, magnesium sulfate) and intramuscular epinephrine. Procedures of interest included peripheral intravenous line (PIV) placement, endotracheal intubation (ETI), supraglottic airway placement, and use of continuous positive airway pressure (CPAP). Our secondary outcome of interest was previous use of albuterol among patients with asthma before EMS presence at scene.

2.7 | Data analysis

We used descriptive statistics to summarize data and presented medians with interquartile ranges for continuous variables and raw number with corresponding percentages for categorical data. We used χ^2 tests and the Wilcoxon rank-sum test to compare characteristics in the severe and nonsevere groups. For secondary outcomes, we reported proportions of patients among those with available data. Analysis was performed using R version 3.5.1 (R Foundation for Statistical Computing, Vienna, Austria).

3 | RESULTS

3.1 | Patient inclusion

Out of 19 246 regional pediatric transports, 1078 (5.6%) met inclusion criteria for this study (Figure 2). The population consisted of 624 (57.9%) males, with a mean age of 8.5 years (standard deviation 4.8 years). Among included patients, 532 (49.4%) met criteria for severe asthma (Table 1).

3.2 | Demographics and transport characteristics

Overall, there were a higher proportion of patients with severe asthma in the ≥12 years age group. Male sex predominated overall, particularly in the nonsevere group. Patients with severe asthma

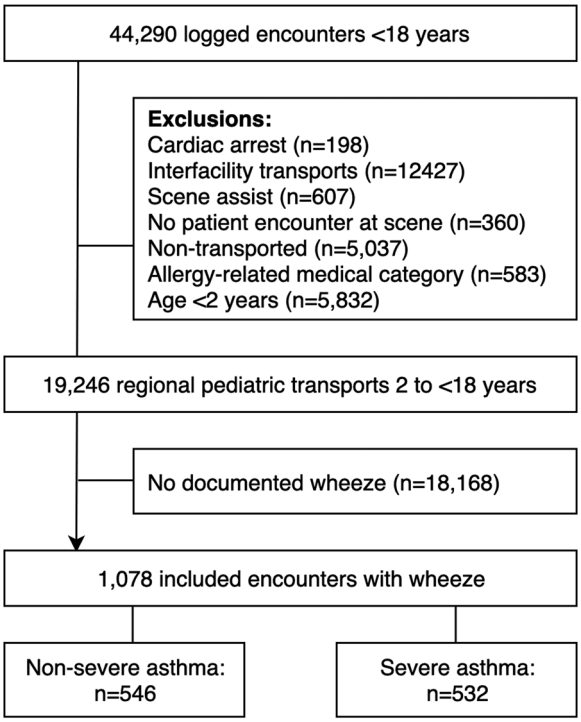

FIGURE 2 Study patient inclusion

TABLE 1 Patient demographics with clinical and transport characteristics

	All patients	Nonsevere	Severe	P*
Number, n (%)	1078	546	532	
Age, n (%)				<.001
Age 2-5 y	427 (39.6)	267 (48.9)	160 (30.1)	
Age 6-11 y	354 (32.8)	246 (45.1)	108 (20.3)	
Age ≥12 y	297 (27.6)	33 (6.0)	264 (49.6)	
Male sex, n (%)	624 (57.9)	336 (61.5)	288 (54.1)	.044
Race, n (%)				.168
White	215 (19.9)	107 (19.6)	108 (20.3)	
Black	426 (39.5)	203 (37.2)	223 (41.9)	
Other/unknown	437 (40.5)	236 (43.2)	201 (37.8)	
Vitals assessment, n (%)				
Any vital assessed	1020 (94.6)	497 (91.0)	523 (98.3)	<.001
Tachypnea for age	425/1014 (41.9)	0/492 (0.0)	425/522 (81.4)	<.001
Tachycardia for age	508/1020 (49.8)	183/497 (36.8)	325/523 (62.1)	<.001
Hypotension of age	18/930 (1.9)	9/442 (2.0)	9/488 (2.0)	.832
Fever	13/36 (36.1)	6/19 (31.6)	7/17 (41.2)	.802
Oxygen desaturation (<90%)	102/1010 (10.1)	39/494 (7.9)	63/516 (12.2)	.030
Year, n (%)				.752
2014	338 (31.4)	172 (31.5)	166 (31.2)	
2015	270 (25.0)	130 (23.8)	140 (26.3)	
2016	236 (21.9)	120 (22.0)	116 (21.8)	
2017	234 (21.7)	124 (22.7)	110 (20.7)	
Day period, n (%)				.142
00:00-05:59	225 (20.9)	121 (22.2)	104 (19.5)	
06:00-11:59	283 (26.3)	127 (23.3)	156 (29.3)	
12:00-17:59	288 (26.7)	148 (27.1)	140 (26.3)	
18:000-23:59	282 (26.2)	150 (27.5)	132 (24.8)	
Time of year, n (%)				.746
Winter	233 (21.6)	123 (22.5)	110 (20.7)	
Spring	258 (23.9)	132 (24.2)	126 (23.7)	
Summer	283 (26.3)	136 (24.9)	147 (27.6)	
Fall	304 (28.2)	155 (28.4)	149 (28.0)	
Income by ZIP code, n (%)[a]				.564
First quartile	315 (29.6)	151 (28.0)	164 (31.2)	
Second quartile	267 (25.1)	134 (24.9)	133 (25.3)	
Third quartile	244 (22.9)	125 (23.2)	119 (22.6)	
Fourth quartile	239 (22.4)	129 (23.9)	110 (20.9)	
Response characteristics				
ALS transport n, (%)	1060 (98.3)	537 (98.4)	523 (98.3)	.956
Response time, minutes; median (IQR)	8 (5-10)	8 (6-10)	7 (5-10)	.186
Scene time, minutes; median (IQR)	11 (8-15)	10 (7-13)	11 (8-16)	<.001
Transport time, minutes; median (IQR)	17 (11-24)	18 (11-24)	16 (11-23)	.337
Monitor use, n (%)	453 (42.0)	193 (35.3)	260 (48.9)	<.001

Abbreviations: ALS, advanced life support; IQR, interquartile range.

[a]IP-code related data were available for 1065 (98.7%) patients (539 in nonsevere group, 526 in severe group).

*P value derived from χ^2 or Wilcoxon rank-sum tests.

more frequently had tachypnea and tachycardia for age and had a longer scene time. There were no significant differences in the nonsevere and severe groups with respect to race, year of transport, time of day of transport, season, income by ZIP code, type of transport, response time, or transport time (Table 1).

3.3 | Interventions performed

Most (64.8%) patients were given at least one dose of albuterol by EMS. Patients with severe asthma were given higher amounts of albuterol and ipratropium bromide compared to those with nonsevere asthma. Patients with severe asthma were more frequently given intravenous methylprednisolone, had an intravenous line placed, were given intramuscular epinephrine, and were provided oxygen. Two patients were given CPAP. No patients required ETI or placement of a supraglottic airway (Table 2.).

3.4 | Prior of use albuterol

Documentation with respect of prior use of albuterol was available in 631 (58.5%) patients, with roughly equal proportions of missing data in both groups. Approximately 2/3 of patients were provided

TABLE 2 Interventions provided to included patients

Intervention category (n)(%)	All patients (N = 1078)	Nonsevere (N = 546)	Severe (N = 532)	P*
Bronchodilator therapy				
Number of doses of albuterol				<.001
None	379 (35.2)	231 (42.3)	148 (27.8)	
One	428 (39.7)	207 (37.9)	221 (41.5)	
Two	238 (22.1)	97 (17.8)	141 (26.5)	
Three	28 (2.6)	11 (2.0)	17 (3.2)	
Four	5 (0.5)	0 (0.0)	5 (0.9)	
Number of doses of ipratropium bromide				
None	807 (74.9)	460 (84.2)	347 (65.2)	
One	251 (23.3)	80 (14.7)	171 (32.1)	
Two	18 (1.7)	6 (1.1)	12 (2.3)	
Three	1 (0.1)	0 (0.0)	1 (0.2)	
Four	1 (0.1)	0 (0.0)	1 (0.2)	
Magnesium	5 (0.5)	0 (0.0)	5 (0.9)	.068
Methylprednisolone	81 (7.5)	13 (2.4)	68 (12.8)	<.001
Epinephrine (intramuscular)				
Given any epinephrine	17 (1.6)	2 (0.4)	15 (2.8)	.003
Number of doses of epinephrine				.005
None	1061 (98.4)	544 (99.6)	517 (97.2)	
One dose	15 (1.4)	2 (0.4)	13 (2.4)	
Two doses	2 (0.2)	0 (0.0)	2(0.4)	
Respiratory support				
Oxygen	280 (26.0)	122 (22.3)	158 (29.7)	.005
Continuous positive airway pressure	2 (0.2)	0 (0.0)	2 (0.4)	.468
Intubation	0 (0.0)	0 (0.0)	0 (0.0)	N/A
Supraglottic airway	0 (0.0)	0 (0.0)	0 (0.0)	N/A
Access				
Peripheral intravenous line placement	180 (16.7)	43 (7.9)	137 (25.8)	<.001
Intraosseous line placement	0 (0.0)	0 (0.0)	0 (0.0)	N/A

*P value derived from χ^2 tests.

albuterol before EMS arrival. A higher proportion of patients in the severe asthma group reported missing or being out of medication compared to those in the nonsevere group (23.1% vs 15.8%; Table 3).

4 | DISCUSSION

In this investigation of a regional EMS cohort of patients with wheezing, we identified that approximately 6% of transports in children ages 2 to 17 were for asthma exacerbations. Of these, approximately one half of asthma exacerbations met criteria for a severe asthma exacerbation. While the majority of patients were given bronchodilator therapy, only a minority were provided steroids, even among those with severe asthma. A larger proportion of patients with severe asthma did not have home access to bronchodilator therapy. These findings provide the basis for future quality improvement and research interventions for pediatric patients transported with asthma.

TABLE 3 Albuterol before EMS transport

	Total	Nonsevere	Severe
Previous use of albuterol not reported	447/1078 (41.5)	236/546 (43.2)	211/532 (39.7)
Received albuterol before EMS	432/631 (68.5)	214/310 (69.0)	218/321 (67.9)
Reported out of medications	123/631 (19.5)	49/310 (15.8)	74/321 (23.1)

Abbreviations: EMS, emergency medical services.

We found that 6% of pediatric patients were transported for likely asthma exacerbations. In one multiagency study comprising of 9956 pediatric transports in Milwaukee county, 13% were transported for respiratory distress and 9.7% were transported for asthma.[9] In another multiagency study evaluating 514 880 transports among 12 EMS agencies affiliated with the pediatric emergency care applied research network, 4.4% were for suspected asthma exacerbations.[10] Our rate of 6% is lies between to these two recent studies.

In the ED, early administration of steroids is associated with improved outcomes, including reduced hospitalization and intensive care unit stays for patients with pediatric asthma.[17,18] While data are limited, trials have suggested that the benefit of early steroid use extends into the prehospital setting. In one study with adults, prehospital administration of methylprednisolone for asthma exacerbations was associated with a two-third reduction in admission

compared to those who only received steroids in the ED.[19] Yet in our cohort only a minority of pediatric patients (7%) were given systemic steroids. This figure was only slightly higher (12%) among patients with severe asthma. PIV placement may be a limiting factor for steroid administration, particularly in younger children.[20] However, guidelines from the National Asthma Education and Prevention Program promote use of oral steroids for patients with asthma exacerbations, which may represent a crucial area for protocol improvements.[21] One retrospective study evaluating the effect of a protocol change suggested that allowing use of oral dexamethasone instead of intravenous methylprednisolone for pediatric patients with asthma evaluated in an ED resulted in decreased hospitalization rates including intensive care unit stays, and increased usage of prehospital steroids.[12] Though this investigation was limited in numbers (n = 482) and requires validation in a multicenter EMS-based prospective cohort, this study identifies an opportunity for protocol improvements in managing pediatric patients with asthma.

Our findings highlight additional opportunities for protocol improvements in managing prehospital pediatric asthma. The use of ipratropium bromide, as either an isolated nebulization or in combination with albuterol, was limited in our cohort as it was in another study evaluating prehospital management of asthma.[22] Ipratropium bromide may be reserved for more serious cases, or provider practice variation may contribute to use of nebulized albuterol alone. Practice variation may be impacted by trials that have suggested no benefit from this medication in children with moderate asthma already treated with albuterol and steroids.[23] One randomized control trial performed in the ED suggested that use of ipratropium bromide in combination with albuterol was associate with a reduced admission rate compared to albuterol alone.[24] Another study identified a correlation between use of ipratropium bromide and shorter hospital length of stay.[25] Similarly, use of magnesium was low in this study. A recent systematic review of 10 randomized controlled trials suggested intravenous magnesium improves respiratory function and reduces hospitalization in children when given in the ED.[26] Further research is required to investigate this medication in the prehospital setting, especially in a pediatric population.

We evaluated albuterol use before EMS arrival for an asthma exacerbation. Though this analysis was complicated by higher rates of missing data, our results suggest that a large proportion of patients with severe asthma do not have access to home medication. To date, one prior study investigating this question with limited numbers has suggested that only a minority of patients (19/61) received bronchodilator therapy before EMS evaluation.[27] The lack of access to albuterol is a major public health concern and could be addressed through primary care practices, at hospital discharge, and by community paramedicine programs targeted for patients with asthma.

The findings from this study also identify avenues for quality improvement among pediatric patients transported with asthma. First, a large proportion of patients (35% overall, 28% among patients with severe asthma), were given no albuterol. Second, the administration of steroids, particularly among patients for whom a PIV is provided, may result in improved outcomes for this subset of patients. Notably, while 26% of patients with severe asthma exacerbations had a PIV placed by EMS, only 13% were given intravenous steroids. Third, adequate documentation with respect to use of bronchodilators before transport by providers is an important step in understanding the severity of exacerbations.

The results from this study are subject to typical limitations from a retrospective chart review, including reporting and recall bias. We used a methodology to capture patients for inclusion that both relied on charted data as well as manual review, however some patients with asthma exacerbations may have been missed. We relied on documentation to identify patients with severe respiratory distress, which may not have been consistent. In one previous study of 27 pediatric patients hospitalized for asthma, documentation of severe respiratory distress was only present in 63% of cases.[28] While the data from this study are derived from multiple EMS agencies, data were collected in a single region from Western Pennsylvania. Finally, we were unable to link prehospital interventions done in this study to hospital treatment and outcomes, a step which will be required to assess the efficacy of interventions over time. Despite these limitations, the findings from the study provide valuable baseline data to guide future efforts to improve the prehospital care of pediatric asthma.

5 | CONCLUSION

In this review of pediatric encounters for asthma in a large EMS system, approximately 6% of patients aged 2 to 17 years were for asthma. Nearly half were categorized as having severe asthma, with at least one sign of respiratory distress. While bronchodilator use was generally high among evaluated patients, use of steroids and adjunctive measures, including magnesium, was low. These findings provide descriptive data on the management of pediatric asthma in the prehospital setting to facilitate future efforts in quality improvement, research, and protocol development.

CONFLICT OF INTERESTS

The authors declare that there are no conflict of interests.

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