A Statewide Study of the Epidemiology of Emergency Medical Services' Management of Pediatric Asthma

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Introduction

Asthma affects an estimated 7 million children (nearly 1 in 10) in the United States.[1] Children (particularly African-Americans and Hispanics), are disproportionately affected by acute exacerbations, emergency department (ED) visits, and hospitalizations.[1–4] Pediatric asthma accounts for over 600,000 ED visits, 150,000 hospitalizations, and $50 billion in healthcare costs annually.[1,2,5]

Previous studies have examined pediatric asthma's epidemiology and best practices for treatment in the ED setting.[3,6] Evidence-based guidelines for ED treatment have been promulgated, recommending administration of first-line short-acting inhaled beta-agonists (albuterol), inhaled ipratropium bromide, and systemic corticosteroids.[7–9] Importantly, studies show that the benefits of systemic corticosteroids are time-sensitive, with earlier administration in the ED conferring decreases in hospital admission, ED length-of-stay (LOS), and relapse rates.[10–12]

Approximately 10% of all pediatric ED patients utilize emergency medical services (EMS) for prehospital management and transport.[13,14] A national study of pediatric EMS encounters found that albuterol was the most frequently administered medication, yet did not offer further detail on pediatric EMS encounters for asthma or respiratory distress.[15] No other current study has examined the epidemiology and treatment of pediatric asthma by EMS.[16] To fill that gap, this study set out to describe the relevant demographic, clinical, and geographic characteristics of pediatric asthma patients treated by EMS in the state with the fourth-largest pediatric population to examine current EMS treatment practices.[17]

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Materials & Methods

Study Design & Setting

This was a retrospective observational study of children treated and transported by EMS for an asthma exacerbation in the state of Florida from 2011–2016. Patients were identified from Florida's EMS Tracking and Reporting System (EMSTARS) database, which contains EMS encounters from over 100 EMS agencies in a state with a population near 21 million, 20% of whom are under 18 years of age.[18, 19] EMSTARS contains 74% of all 911 EMS encounters from 2011–2016.[19] Both the University of Florida and Florida Department of Health Institutional Review Boards approved the study with waiver of informed consent.

Inclusion & Exclusion Criteria

Inclusion criteria were patients ages 2 to 18 years, transported by EMS to an ED, with a primary symptom of difficulty breathing, an EMS provider primary impression of respiratory distress, and who were administered inhaled albuterol by EMS at least once (to indicate an acute exacerbation). EMSTARS does not contain an asthma-specific diagnosis, therefore we chose to combine respiratory distress with administration of albuterol for the inclusion criteria. Patients were excluded if they were classified as a trauma/injury, seizure, pregnancy-related complication, or interfacility transport. Patients less than 2 years of age were excluded to avoid confounding with wheezing due to bronchiolitis. To test the albuterol administration inclusion criteria, we performed a sensitivity analysis examining characteristics of all EMSTARS patients ages 2–18 with an EMS provider primary impression of respiratory distress.

Data Variables

For vital signs, the first available recorded observation per vital sign was used (as many EMS treatment decisions are made based on the first assessed value).[20] EMS scene time was calculated as the interval between EMS arrival on scene and when EMS left the scene. EMS transport time was calculated as the interval between EMS leaving the scene and arriving at the destination ED. *A priori*, the investigators considered any scene or transport times of negative, zero, or less than three minutes as potentially miscoded, and so time intervals less than three minutes were excluded from the analysis (<2% of values).

Patients were classified by severity (mild, moderate, severe, and critical) using the 2007 National Heart, Lung, and Blood Institute's (NHLBI) Expert Panel Report-3's recommended classification for asthma exacerbation severity.[7] Not all components of the NHLBI's scoring system were available in the EMSTARS database, therefore a modified version was created. In this modification, the variables "breathlessness," "talks in," "use of accessory muscles/suprasternal retractions," and "wheeze" were substituted with EMSTARS' "respiratory effort" (a graded scale with values: normal, increased, fatigued, and absent). Alertness, heart rate, respiratory rate, and oxygen saturation were used per the original scoring system with age-adjusted normal values for heart rate and respiratory rate.[21] Pulsus paradoxus, peak expiratory flow, and arterial oxygen pressure are NHLBI score components, but are not usually measured by EMS and not available in EMSTARS, so those were removed from

the modified version. Patients' overall severity score comprised the highest value from each component of the modified classification (Table 1).

Data Analysis

Demographic, clinical, and EMS characteristic variables were analyzed using descriptive statistics, including frequencies, percentages, mean, standard deviation, median, and interquartile ranges, as appropriate. Continuous variables were compared using unpaired t-test and Kruskal-Wallis tests, as appropriate. Categorical variables were compared using the Chi-Square test, or Fisher Exact Test when there were less than 10 observations (as a conservative approach).[23] Whether variables were normally distributed was tested using the Shapiro-Wilk test, or the Kolmogorov-Smirnov test for sample sizes greater than 2,000.[24] Missing data was excluded from the analysis given that EMSTARS comprises data from multiple heterogeneous EMS agencies, which precluded reliable interpretation of whether data was missing at random.

Given the known disparate impact of pediatric asthma on African-American children,[3, 4] we chose to focus our geographic analysis on population-based disparities. Geospatial analysis classified patients by the county in which the responding EMS agency was based (as recorded in EMSTARS). Study population disparities were analyzed by calculating the difference between expected and observed frequencies of patient events by demographic variables such as race. Missing or unknown demographic variables were excluded from the analysis. Observed frequencies were taken from EMSTARS, and expected frequencies were based on the 2010 United States Census data on race and percentage of population under 18 years of age.[22] Population disparities by county were then calculated using z-scores for the difference between observed and expected frequencies.

Since ED-based research and guidelines recommend early administration of systemic corticosteroids for pediatric asthma exacerbations,[7–12] we analyzed characteristics for patients who did and did not receive systemic corticosteroids from EMS. First, univariate logistic regression was employed to screen all variables for their association with EMS systemic corticosteroid administration. Afterwards we performed a Bonferroni correction for multiple comparisons. A p value of < 0.20 was the threshold for candidate variables in the multivariable modeling process. A parsimonious multivariable logistic regression model was created using Akaike's Information Criterion (AIC), area-under-the-curve (AUC), the Hosmer and Lemeshow Goodness-of-Fit test, and total number of variables as discrimination and calibration measures (Supplemental Digital Content 1). The final model's significant predictors are presented with odds ratios (OR) and their corresponding 95% confidence intervals (CI). Statistical analysis was performed using SAS® version 9.4 (Cary, NC). Geospatial analysis was performed using ArcGIS Desktop 10.4.1 (Redlands, CA).

Results

A total of 11,226 patients met the inclusion criteria from 2011–2016 (Figure 1). Demographic, clinical, and EMS characteristics are presented for the entire study population (Table 2). Notably, 49% of patients were African-American, and 60% were male. Most were treated by a Paramedic-level Emergency Medical Technician (EMT) (85%) and were

transported from a home or residence (54%). Of note, parent or patient choice was the most frequent reason for choosing the destination facility (44%), as compared to the closest facility (41%). Using the modified-NHLBI severity classification, most patients scored moderate (43%), followed by severe (39%), mild (12.6%), then critical (3.2%). In addition to albuterol, 36.5% of patients received at least one administration of ipratropium bromide, 20.5% received supplemental oxygen, and <1% received magnesium sulfate. With regards to systemic corticosteroids, 1,036 (9.3%) received intravenous (IV) methylprednisolone and only 12 (<1%) of patients received dexamethasone (IV or oral). No other systemic corticosteroids (IV, intramuscular, or oral) were administered in the study sample. The three most frequent procedures performed were IV access in an extremity (12.4%), cardiac monitoring (11.3%), and electrocardiogram (9.7%). Less than one percent of patients required bag-valve mask ventilation, continuous positive airway pressure, or intubation. Missing data are varied greatly by variable (Table 2).

To test whether the albuterol inclusion requirement significantly altered results, a sensitivity analysis examined the number of patients aged 2–18 years with a provider primary impression of respiratory distress, but who *did not* receive albuterol from EMS. This produced 26,008 patient records, 22,500 (86.5%) of which were encounters attended to by EMT-paramedics, who are licensed to give albuterol for wheezing and/or asthma. Only 12 (<1%) of the 26,008 calls were attended to by EMT-Basic providers, who are not licensed to give albuterol or other medications for respiratory distress. The remaining patients were treated by intermediate-level EMTs or nurses. Therefore, it appears that in the vast majority of those excluded encounters the treating EMS providers did not believe the patient was suffering from an asthma exacerbation. As evidenced by Figure 1, for patients who did receive albuterol but were excluded, the primary symptoms and provider impressions were indicative of other processes besides asthma, such as trauma or allergic reactions.

County-based analysis of population disparities revealed a disparate impact on African-American pediatric patients with asthma. County level differences in proportion of African-Americans were normally distributed (W = 0.976, p value = 0.297, Shapiro-Wilk test). Several counties had frequencies of EMS encounters for that population much greater than expected based on population percentage (Figure 2). Of the 7 counties with z-scores greater than 1 standard deviation above the mean, 4 (including the county with the highest positive z-score) are classified as rural by the Florida Department of Health.[22,25]

We compared characteristics between patients who did and did not receive systemic corticosteroids (in the form of methylprednisolone only, as dexamethasone had few administrations). Patients who received systemic corticosteroids were older and had longer EMS scene and transport times (all p<0.0001) (Table 2). Also, systemic corticosteroid administration varied directly by respiratory effort (p<0.0001) and modified-NHLBI severity score (p<0.0001), and inversely by total Glasgow Coma Score (p=0.0104) and level of alertness (p<0.0001), all indicating a more severe clinical presentation. However, systemic corticosteroid administration *did not* vary by respiratory rate (p=0.54), heart rate (p=0.19), or pulse oximetry (p=0.73); nor did it vary by race (p=0.068) or ethnicity (p=0.17). Although 1,036 patients were documented as receiving systemic corticosteroids, IV access was only documented for 985 patients. A Bonferroni correction for multiple comparisons

decreased the adjusted Type I error to 0.0012, which made gender, EMS encounter year, GCS, and oropharyngeal airway no longer significant.

The results of the multivariable logistic regression evaluating factors associated with EMS systemic corticosteroid administration demonstrated that the most significant predictors all related to medication administration (Table 3, Supplemental Digital Content 1). The strongest predictors were IV access (OR 33.3, 95% CI 24.4–45.6), administration of a subcutaneous or intramuscular injection (OR 3.6, 95% CI 1.3–10.3), and concomitant administration of other medications such as IV magnesium sulfate (OR 5.0, 95% CI 3.4–7.3) or inhaled ipratropium bromide (OR 2.4, 95% CI 2.0–2.8). Other significant predictors included labored respiratory effort (OR 1.6, 95% CI 1.4–1.9), and race other than African-American or white (OR 1.3, 95% CI 1.0–1.6). Patient or family choice of the destination facility was predictive of *not* receiving systemic corticosteroids (OR 0.7, 95% CI 0.6–0.9).

Discussion

This is the largest study to describe the epidemiology of EMS treatment of pediatric asthma. In this statewide study, we found disparate impacts on rural African-American children, as well as underutilization of evidence-based asthma treatments such as systemic corticosteroids and ipratropium bromide.

Nearly half of the study population was African-American (49%), which is much larger than the statewide African-American population (16.9%).[18] However, this proportion is similar to other ED and population-based studies of disparities in asthma exacerbation frequency with respect to African-American patients.[2,3,26] Although previous research has found evidence that African-Americans utilize EMS at a higher frequency, given that patients arriving via EMS are typically higher acuity, these findings underscore the disproportionate impact acute asthma exacerbations have on the African-American population.[27,28]

The typical epidemiologic description of the disparate impact of asthma on African-American populations describes urban, inner-city environments.[29] However, this study's geographic analysis reveals a geographic disparity of EMS asthma encounters involving African-Americans living in rural counties. The current rural health crisis of reduced service availability and its impact on emergency medical services is receiving increasing media and scholarly attention.[30,31] However this study's rural asthma EMS encounters may also reflect genetic, socioeconomic, or environmental factors in addition to the current rural healthcare crisis. Future studies should seek to define the etiology of these significant geographic disparities of asthma exacerbations affecting rural African-American children. Regardless of etiology, these findings underscore that the rural health crisis is affecting other racial groups in addition to white populations.[31]

With respect to asthma treatment, we found that systemic corticosteroids (in the form of methylprednisolone) are reserved for the small (<10%) percent of generally more severe patients. However, systemic corticosteroids are more liberally administered in the ED (usually via oral administration), as they confer benefits for mild, moderate, and severe asthma exacerbations.[7,8,10–12] Furthermore, early administration of systemic corticosteroids

in the ED has proven to reduce ED LOS and hospitalization rates.[10–12] Therefore would even earlier EMS administration of systemic corticosteroids further improve patient outcomes? A study of one EMS agency that liberalized systemic corticosteroid use (in the form of oral dexamethasone) for all pediatric asthmatics found a decrease in ED LOS of nearly two hours, as well as a decrease in hospital admission rates from 30% to 21%.[32] However, that same study also found very low overall rates of systemic corticosteroid administration, only increasing from 11% to 18% after the protocol change.[32] Additionally, in this study approximately one-third of patients received ipratropium bromide, which also has proved to reduce hospitalizations when combined with albuterol in the pediatric ED setting.[7,8,33,34] Therefore, it appears many EMS pediatric asthma patients miss the opportunity to receive medications prior to ED arrival that could markedly change their clinical outcomes. Those treatments may not be emphasized in the implementation of and education regarding pediatric EMS asthma protocols.

EMS medication use is typically governed by local agency protocols. In this study, although the percentage of patients who received systemic corticosteroids or ipratropium bromide varied by county, most counties did utilize both medications (data available upon request). In Florida, most counties are serviced by one EMS agency, although some more-populated urban counties contain more than one EMS agency.[19] Given the greater than 50 individual EMS agencies in Florida, we were not able to ascertain each agency's asthma or pediatric asthma protocol during the study period. However, given our results, it appears that either by protocol or practice, EMS providers infrequently (<1% of encounters in this study) administer oral systemic corticosteroids to pediatric asthma patients. The three most significant predictors of systemic corticosteroid use from the adjusted logistic regression were IV access, subcutaneous or intramuscular injection, and another IV medication (magnesium sulfate), perhaps indicating more severe patients who required IV access for other therapies. *This suggests a barrier to more widespread EMS systemic corticosteroid administration may be pediatric IV placement.* Indeed, previous studies have found low frequencies and increasing difficulties with EMS IV placement with younger ages, which may explain this study's findings of increasing age conferring greater odds of receiving systemic corticosteroids.[35,36] Other potential barriers to systemic corticosteroid administration previously identified in the ED literature include markers of severity, female sex, and longer duration of symptoms.[37] Similarly, this study found that patients with labored breathing who scored severe on the modified-NHLBI severity scoring system were more likely to receive systemic corticosteroids.

In addition to clinical characteristics, this study found significantly longer EMS scene and transport times for patients who received systemic corticosteroids. Scene time increases may be a direct reflection of the time required for IV placement and medication administration. Transport time increases may reflect a decision by EMS providers to administer methylprednisolone *based on* longer transport times. Despite the scene time increase, EMS providers may be best-suited for efficient administration of systemic corticosteroids. A previous study of adult asthma patients compared the time from EMS provider arrival on scene to methylprednisolone administration, with the time from patient ED arrival to methylprednisolone administration.[38] The average time from arrival to EMS administration was 15 minutes (SD 7 minutes), compared with 40 minutes (SD 22 minutes)

for ED-treated patients.[38] Since IV placement may be a larger barrier in children than adults, exploration of alternative routes of systemic corticosteroid delivery (such as oral prednisolone or oral or intramuscular dexamethasone) are needed to optimize pediatric asthma outcomes.

Limitations

This study is a retrospective study of one state and therefore its conclusions may not be generalizable to other areas of the United States. However, Florida is the state with the fourth-largest pediatric population and is one of the largest contributors to the National EMS Information Systems' database.[17, 19] As such, EMSTARS data contains a voluminous amount of EMS data worthy of examination. EMSTARS does not contain data from every EMS agency in Florida, which may be reflected in this study's results, particularly the geographic analysis. However, the 100 agencies reporting to EMSTARS comprise 74% of all 911 EMS calls made during the study period.[19] Although interfacility transports were intentionally excluded, there may such patients in the dataset not coded as such. Additionally, the EMSTARS dataset does not identify ground versus helicopter transports. Another limitation is that EMSTARS contains unique identifiers for each patient encounter, so we were unable to ascertain if any patients were repeat encounters.

EMSTARS does not include what medications patients may have received prior to EMS arrival, including oral systemic corticosteroids that may have been prescribed in case of an exacerbation. However, in our experience primary care providers rarely prescribe oral corticosteroids without an acute patient visit. EMSTARS does not contain hospital data, and so this study does not include patient outcomes. The modified NHLBI severity score used in this study has not been validated in the EMS setting, and although it represents a best estimate of severity, results should be interpreted in that context.

EMSTARS does not contain a data variable for 'Past Medical History', nor does it contain any free text narrative for each patient encounter. Therefore, we were unable to ascertain if any patients had a prior history of asthma to increase the accuracy of our inclusion and exclusion criteria. The inclusion criteria of receiving albuterol from EMS was specifically designed to include patients with *acute asthma exacerbations*. It may be possible that some EMS patients with asthma exacerbations did not receive albuterol, or that that some patients received albuterol who were not having an asthma exacerbation. However, the inclusion criteria's sensitivity analysis revealed that the majority of all patients ages 2–18 with respiratory distress in EMSTARS were treated by EMT-paramedics. EMT-paramedics are highly trained in the indications for and administration of medications for respiratory conditions, including asthma. Therefore, we believe the albuterol inclusion criteria most likely selected for patients suffering from an asthma exacerbation and excluded those with respiratory distress due to other causes (e.g., pneumonia, croup). Additionally, requiring the primary symptom and provider primary impression to indicate respiratory distress filtered out wheezing potentially due to other causes other than asthma (e.g., trauma, allergic reaction) as evidenced by Figure 1. However it is possible that some of those excluded patients were indeed suffering from an asthma exacerbation.

Similar to other research utilizing large EMS datasets, EMSTARS variables contain missing data (as noted in Table 2). When large amounts of values are missing, this may bias the results or reduce their precision.[39] The geospatial analysis was missing data for 8 out of Florida's 59 counties. Many counties, especially in rural areas, had low numbers of patient encounters, (e.g., 9 counties with less than 10 records), and so results should be interpreted based on those small sample sizes. However, as compared with other previously published research, the majority of variables missing in this study was low.[40]

Conclusions

In this statewide study, the vast majority of pediatric asthma patients treated by EMS did not receive systemic corticosteroids or inhaled ipratropium bromide, two evidence-based ED treatments that reduces ED LOS and hospitalization rates. Thus, data from the present study demonstrate a need to educate EMS providers on the potential benefits of those medications and the need to update EMS protocols. This study also identifies disproportionate numbers of EMS encounters involving rural African-American children. Further work is required to discern the etiology of demographic and geographic disparities, as well as barriers and enablers to EMS administration of systemic corticosteroids. The results of this study suggest the need for a randomized controlled trial of EMS administered oral systemic corticosteroids.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements

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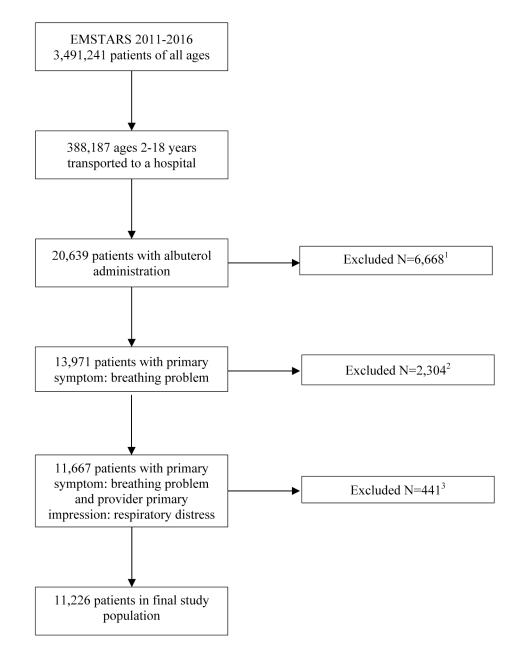
EMSTARS 2011-2016
3,491,241 patients of all ages

↓

388,187 ages 2-18 years
transported to a hospital

↓

20,639 patients with albuterol administration → Excluded N=6,668[1]

↓

13,971 patients with primary symptom: breathing problem → Excluded N=2,304[2]

↓

11,667 patients with primary symptom: breathing problem and provider primary impression: respiratory distress → Excluded N=441[3]

↓

11,226 patients in final study population

Figure 1: Study Inclusion and Exclusion Criteria

[1]Excluded primary symptoms (N): Bleeding (25), change in responsiveness (199), choking (15), death (1), device/equipment problem (1), diarrhea (2), drainage/discharge (4), fever (177), malaise (94), mass/lesion (1), mental/psych (44), nausea/vomiting (4), not known or missing (5,556), pain (137), palpitations (1), rash/itching (201), swelling (80), transport only (43), weakness (46), wound (1)

[2]Excluded primary impressions: Behavioral / psychiatric disorder (28), diabetic symptoms (1), cardiac arrest (5), airway obstruction (90), vaginal hemorrhage (1), altered level of consciousness (21), syncope/fainting (5), seizure (14), hyperthermia (12), hypothermia (1), chest pain (30), abdominal pain (42), respiratory arrest (28), sexual assault/rape (1), traumatic injury (11) poisoning/drug ingestion (1), inhalational injury (7), stings/venomous

bites (1), allergic reaction (493), fever (50), general malaise (97), heart-related illness (12), intentional drug use (1), not known or missing (1423), other non-traumatic pain (541), sepsis (4)

[3]Childbirth (3), seizure (38), interfacility transfer (160) or trauma (240) as indicated by other EMS procedure or classification codes
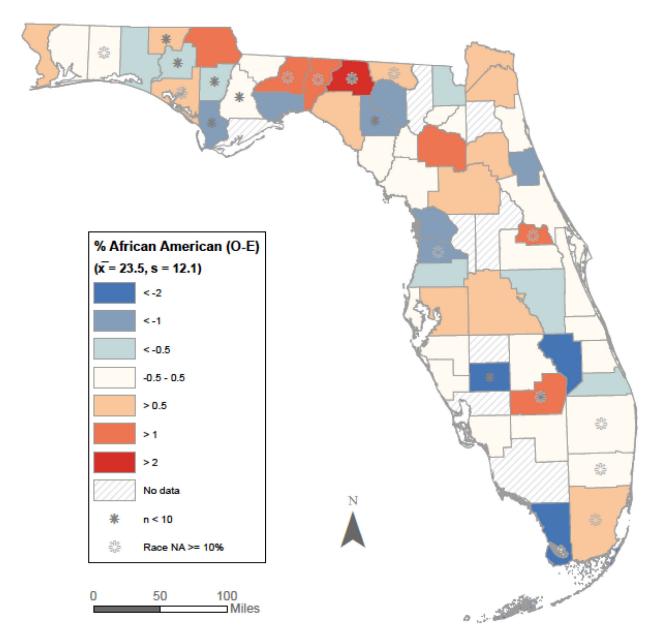
Figure 2.
Legend: Distribution of Difference in Observed Versus Expected Percent of African-American EMSTARS Asthma Patients by County in Florida. Shading indicates numerical distribution of z scores.

Table 1:

Modified-NHLBI Asthma Severity Classification[*]

	Mild	**Moderate**	**Severe**	**Critical**
Level of Alertness	Alert	Verbal	Painful	Unresponsive
Respiratory Effort	Normal	Labored	Fatigued	Absent
Respiratory Rate (breaths per minute)				
2-5 years	10-29	30-40	>40	<10
6-11 years	10-24	25-35	>35	<10
12-18 years	10-19	20-30	>30	>10
Pulse Rate (beats per minute)				
2-5 years	100-119	120-140	>140	<100
6-11 years	60-109	110-130	>130	<60
12-18 years	60-99	100-120	>120	<60
Pulse Oximetry	> 95%	90-95%	80-89%	<80%

NHLBI = National Heart Lung and Blood Institute

[*] Derived from Reference 7 & 21

Table 2:

Characteristics of EMS pediatric asthma patients in Florida from 2011-2016 overall, and by those who did and did not receive systemic corticosteroids

	Total N=11,226	Missing N (%)	Systemic Corticosteroids [1] N=1,036	No Systemic Corticosteroids N=10,190	P Value [*]
Patient Demographics, N (%)					
Age years (Median, IQR)	9 (5-13)	0 (0%)	12.5 (8-16)	8 (5-13)	<0.001 [*]
Male Gender	6726 (60%)	2 (<1%)	586 (56.5%)	6140 (60%)	0.02 [*]
Race		832 (7.4%)			0.07
African-American or Black	5491 (49.0%)		487 (47.0%)	5004 (49.1%)	
White	3325 (30.0%)		334 (32.2%)	2991 (29.4%)	
Other	1377 (12.3%)		177 (17.0%)	2802 (27.5%)	
Ethnicity		1923 (17.1%)			0.17
Non-Hispanic or Latino	7847 (70.0%)		816 (78.8%)	7031 (69.0%)	
Hispanic or Latino	1456 (13.0%)		169 (16.3%)	1287 (12.6%)	
EMS Characteristics, N (%)					
EMS Encounter Year		0 (0%)			0.003 [*]
2011	1782 (15.8%)		147 (8.0%)	1635 (16.0%)	
2012	1944 (17.3%)		185 (9.5%)	1759 (17.3%)	
2013	2070 (18.4%)		152 (7.3%)	1918 (18.9%)	
2014	1981 (17.6%)		205 (10.0%)	1776 (17.4%)	
2015	1935 (17.2%)		186 (9.6%)	1749 (17.2%)	
2016	1514 (13.4%)		161 (10.6%)	1353 (13.3%)	
EMS Level of Service		0 (%)			<0.001 [*]
EMT-Paramedic	9555 (85%)		938 (90.5%)	8617 (84.6%)	
EMT-Basic	2 (<1%)		0 (0%)	2 (<1%)	
Other [2]	1669 (14.9%)		98 (<1%)	1571 (15.4%)	
Response Mode to Scene		0 (0%)			0.07
Lights and Sirens	10,445 (93.0%)		966 (93.2%)	9479 (93.0%)	
No Lights and Sirens	461 (4.1%)		35 (<1%)	426 (3.8%)	
Other	320 (2.9%)		35 (<1%)	285 (2.7%)	

	Total N=11,226	Missing N (%)	Systemic Corticosteroids [1] N=1,036	No Systemic Corticosteroids N=10,190	P Value *
Scene Location Type		578 (5.1%)			<0.001 *
Home/Residence	6096 (54.3%)		591 (57.1%)	5505 (54.0%)	
Business	993 (8.9%)		132 (12.7%)	861 (8.5%)	
Health Care Facility	936 (8.3%)		83 (8.0%)	853 (8.4%)	
Public Building (School, etc.)	919 (8.2%)		61 (5.9%)	858 (8.4%)	
Other	1704 (15.2%)		143 (13.8%)	1561 (15.3%)	
Transport Mode from Scene		0 (0%)			<0.001 *
No Lights and Sirens	5690 (50.7%)		455 (44%)	5235 (51.4%)	
Lights and Sirens	5281 (47.0%)		555 (53.6%)	4726 (46.4%)	
Other	255 (2.2%)		26 (<1%)	229 (2.2%)	
Reason for Choosing Destination		304 (2.7%)			<0.001 *
Closest Facility	4613 (41.0%)		460 (44.4%)	4153 (40.8%)	
Parent/Patient Choice	5005 (44.5%)		474 (45.8%)	4531 (44.5%)	
Protocol	679 (6.1%)		59 (5.7%)	620 (6.1%)	
Specialty Resource Center	382 (3.4%)		27 (2.6%)	355 (3.5%)	
Other	243 (2.2%)		16 (1.5%)	227 (2.2%)	
Scene Time Minutes (Median, IQR)	11.4 (9-15)	124 (1.1%)	13 (10-17)	12 (8.2-15.6)	<0.001 *
Transport Time Minutes (Median, IQR)	13 (8.9-18.8)	193 (1.7%)	14 (10-19)	12.7 (8.6-18.4)	<0.001 *
Patient Clinical Characteristics					
Systolic Blood Pressure mmHg (Mean, SD)	121.3 (19.1)	1256 (11.2%)	127.2 (17.5)	120.7 (19.1)	<0.001 *
Diastolic Blood Pressure mmHg (Mean, SD)	76.4 (14.8)	1484 (13.2%)	78.8 (15.2)	76.2 (14.7)	<0.001 *
Heart Rate beats per minute (Mean, SD)	120.5 (25.7)	288 (2.6%)	119.5 (25.4)	120.6 (25.8)	0.19
Respiratory Rate breaths per minute (Mean, SD)	27.3 (10.9)	444 (4.0%)	27.1 (9.8)	27.3 (11.0)	0.54
Pulse Oximetry percentage (Median, IQR)	98 (96-100)	407 (3.6%)	99 (96-100)	98 (96-100)	0.73
Respiratory Effort, N (%)		2254 (20.0%)			<0.001 *
Normal	5683 (50.6%)		459 (44.3%)	5224 (51.2%)	
Labored	3016 (26.9%)		396 (38.2%)	2620 (25.7%)	
Fatigued	258 (2.3%)		37 (3.6%)	231 (2.2%)	

	Total N=11,226	Missing N (%)	Systemic Corticosteroids[1] N=1,036	No Systemic Corticosteroids N=10,190	P Value *
Absent	15 (<1%)		1 (<1%)	14 (<1%)	
Glasgow Coma Score (Median, IQR)	15 (15-15)	913 (8.1%)	15 (15-15)	15 (15-15)	0.01 *
Level of Alertness, N (%)		1206 (10.7%)			<0.001 *
Alert	9791 (87.2%)		900 (86.9%)	8891 (87.3%)	
Verbal	87 (<1%)		16 (1.5%)	71 (<1%)	
Painful	46 (<1%)		11 (1.0%)	35 (<1%)	
Unresponsive	32 (<1%)		5 (<1%)	27 (<1%)	
NHLBI Severity Score Classification[3], N (%)		246 (2.9%)			<0.001 *
Mild	1418 (12.6%)		97 (9.4%)	1321 (13.0%)	
Moderate	4828 (43.0%)		397 (38.3%)	4431 (43.5%)	
Severe	4377 (39.0%)		485 (46.8%)	3892 (38.2%)	
Critical	357 (3.2%)		29 (2.8%)	328 (3.2%)	
Medications[4], N (%)					
Number Albuterol per Patient (Mean, SD)	1.24 (0.52)	2106 (7.3%)[5]	1.5 (0.73)	1.2 (0.48)	<0.001 *
Methylprednisolone	1036 (9.2%)		1036 (100%)	0 (0%)	-
Ipratropium Bromide	4095 (36.5%)		618 (59.7%)	3477 (31.0%)	<0.001 *
Oxygen	5576 (49.7%)		699 (67.5%)	4877 (47.9%)	<0.001 *
Magnesium Sulfate	168 (1.5%)		99 (9.6%)	69 (<1%)	<0.001 *
Normal Saline	755 (6.7%)		212 (20.5%)	543 (5.3%)	<0.001 *
Epinephrine (1:1000)	202 (1.8%)		60 (5.8%)	142 (1.4%)	<0.001 *
Procedures[4], N (%)					
Venous Access-Extremity	4035 (35.9%)	7006 (19.3%)[5]	985 (95.1%)	3050 (29.9%)	<0.001 *
Cardiac Monitor	3975 (35.4%)		364 (35.1%)	3611 (35.4%)	0.85
Electrocardiogram	3284 (29.3%)		513 (49.5%)	2771 (27.2%)	<0.001 *
Assessment-Adult	2055 (18.3%)		229 (22.1%)	1826 (17.9%)	<0.001 *
Assessment-Pediatric	2558 (22.8%)		194 (18.7%)	2364 (23.2%)	0.001 *

	Total N=11,226	Missing N (%)	Systemic Corticosteroids [1] N=1,036	No Systemic Corticosteroids N=10,190	P Value [*]
Bag-Valve Mask Ventilation	38 (<1%)		5 (<1%)	33 (<1%)	0.39
CPAP	29 (<1%)		10 (<1%)	19 (<1%)	<0.001 [*]
NPA	92 (<1%)		12 (1.2%)	80 (<1%)	0.20
OPA	47 (<1%)		0 (0%)	47 (<1%)	0.02 [*]
Intubation	24 (<1%)		2 (<1%)	22 (<1%)	0.89
Suction	52 (<1%)		3 (<1%)	49 (<1%)	0.63
Online Medical Direction	104 (<1%)		0 (0%)	104 (1.0%)	0.001 [*]
SQ or IM Injection	24 (<1%)		9 (<1%)	15 (<1%)	<0.001 [*]
IO-Adult	6 (<1%)		1 (<1%)	5 (<1%)	0.44
IO-Pediatric	4 (<1%)		0 (0%)	4 (<1%)	0.52
CPR	1 (<1%)		0 (0%)	1 (<1%)	0.75

P Values represent comparison between steroid and no steroid groups.

[*]
Indicates significance at p<0.05.

Categorical variables are represented by N (percentage).

Normally distributed continuous variables are described with mean and standard deviation (SD).

Non-normally distributed continuous variables are described with medians and interquartile ranges (IQR), from the 25th percentile to the 75th percentile.

Continuous variables are compared using Student's T-Test (for normally distributed variables) and Kruskal-Wallis tests (for non-normally distributed variables).

Categorical variables are compared using Chi-Square test, or Fisher Exact tests if any observation was less than ten.

[1]
Methylprednisolone counted as systemic corticosteroid. As there were only 12 administrations of dexamethasone during the study period, dexamethasone was not included in the analysis. No other systemic corticosteroids were administered in the study population.

[2]
"Other" for EMS Level of Service includes nurses or physicians.

[3]
Score of mild, moderate, severe, or critical represent the highest ranking on the categories of modified 2007 National Heart, Lung, and Blood Institute's (NHLBI) Expert Panel Report-3's recommended system for classifying asthma exacerbation severity (Formal Evaluation of Asthma Exacerbation Severity in the Urgent or Emergent Care Setting – Table 1 & Reference 6).

[4]
N and percentage represent number of patients who were administered that medication or procedure.

[5]
N and percentage represent number of missing data for all medications or procedures administered (total N=29,020 for medications and N=36,267 for procedures).

CPAP = continuous positive airway pressure, CPR = cardiopulmonary resuscitation, EMS = Emergency medical services, EMSTARS = Emergency Medical Services Tracking and Reporting System, EMT = Emergency Medical Technician, IM = intramuscular, IO = intraosseous, SQ = subcutaneous, NPA = nasopharyngeal airway, OPA = oropharyngeal airway.

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Table 3:

Multivariable logistic regression results: Significant predictor variables for EMS administration of systemic corticosteroids[1,2]

Variable	Odds Ratio	95% Confidence Limits	
Extremity Intravenous Access	33.4	24.4	45.6
Magnesium Sulfate administration	5.0	3.4	7.3
Subcutaneous or Intramuscular Injection	3.6	1.3	10.3
Ipratropium Bromide administration	2.4	2.0	2.8
Electrocardiogram	1.9	1.6	2.2
Oxygen administration	1.8	1.5	2.2
Labored Respiratory Effort	1.6	1.4	1.9
Adult Assessment	1.5	1.3	1.9
Normal Saline administration	1.5	1.2	1.8
Severe (per modified-NHLBI severity score)	1.4	1.2	1.6
Pediatric Assessment	1.3	1.0	1.6
Race other than Black or White	1.3	1.0	1.6
Patient Age (years)[3]	1.0	1.0	1.0
Patient Choice of Destination Facility	0.7	0.6	0.9

EMS = Emergency Medical Services, NHLBI = National Heart Lung and Blood Institute

[1] Methylprednisolone counted as systemic corticosteroid. As there were only 12 administrations of dexamethasone over the study period, dexamethasone was not included in this analysis. No other systemic corticosteroids were administered in the study sample.

[2] Hosmer-Lemeshow goodness-of-fit test = 0.3609, Model AUC = 0.895, AIC 4175.

[3] Odds of steroid administration increased by increasing years of age, OR 1.023, 95% CI 1.005 – 1.041.