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Clinical Pathway Improves Pediatrics Asthma Management in the Emergency Department and Reduces Admissions

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Abstract

Objective—Poor adherence to NIH Asthma Guidelines may result in unnecessary admissions for children presenting to the emergency department (ED) with exacerbations. We determine the effect of implementing an evidence-based ED clinical pathway on corticosteroid and bronchodilator administration and imaging utilization, and the subsequent effect on hospital admissions in a US ED.

Methods—Prospective, interventional study of pediatric (< 21 years) visits to an academic ED between 2011 and 2013 with moderate-severe asthma exacerbations. A multidisciplinary team designed a one-page clinical pathway based on NIH guidelines. Nurses, respiratory therapists, and physicians attended educational sessions prior to pathway implementation. Adjusting for demographics, acuity, and ED volume, we compared timing and appropriateness of corticosteroid and bronchodilator administration, and chest radiograph (CXR) utilization with historical controls from 2006–2011. Subsequent hospital admission rates were also compared.

Results—379 post-intervention visits were compared with 870 controls. Corticosteroids were more likely to be administered during post-intervention visits (96% vs. 78%, adjusted OR 6.35; 95%CI 3.17–12.73). Post-intervention, median time to corticosteroid administration was 45 minutes faster (RR 0.74; 95%CI 0.67–0.81) and more patients received corticosteroids within 1 hour of arrival (45% vs 18%, OR 3.5; 95%CI 2.50–4.90). More patients received >1 bronchodilator dose within 1 hour (36% vs 24%, OR 1.65; 95%CI 1.23–2.21) and fewer received CXRs (27% vs 42%, OR 0.7; 95%CI 0.52–0.94). There were fewer admissions post-intervention (13% vs. 21%, OR 0.53; 95%CI 0.37–0.76).

Conclusion—A clinical pathway is associated with improved adherence to NIH guidelines and, subsequently, fewer hospital admissions for pediatric ED patients with asthma exacerbations.

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Keywords

Steroid; Emergency medicine; Clinical Guidelines; Pediatrics; Crowding; Quality of care; NIH guidelines; Imaging Utilization; Exacerbation

INTRODUCTION

Asthma is responsible for approximately 700,000 ED visits and 200,000 hospitalizations for children annually in the U.S.[1] The National Institute of Health (NIH) Asthma Guidelines recommend prompt administration of systemic corticosteroids for children with exacerbations who fail to respond promptly and completely to inhaled bronchodilators (up to 3 doses in the first hour).[2] Systemic corticosteroids, hereafter referred to as corticosteroids, are one of the primary evidence-based therapies for asthma exacerbations.[2–5] Corticosteroids decrease rates of admission and ED returns, [6, 7] decrease hospital length of stay (LOS), [8] improve pulmonary index scores [9, 10] and possibly improve quality of life for children and their families.[11]

Importantly, best outcomes for asthma exacerbations are achieved with timely treatment with corticosteroids.[7–12] In the original randomized controlled trials of efficacy, corticosteroids were administered within one hour of ED arrival. [6, 7] Several recent studies have confirmed that timely corticosteroid administration is associated with reduced odds of admission [13–15] and that every 30-minute delay in corticosteroid administration is associated with a nearly 20% increased odds of admission.[14] Consequently, the proportion of children receiving timely corticosteroids is a measure of ED quality of care.[16–18]

Despite this evidence and the NIH guidelines, corticosteroids are often under-prescribed for children seen in the ED for asthma exacerbations.[11, 17, 19–23] In addition, frequent delays in corticosteroid administration (52–78% of visits) have been reported.[13–15, 21, 22] Studies from Canada, United Kingdom, South America, and Australia have demonstrated the value of ED clinical pathways in the management of pediatric asthma exacerbations. Pathways have been associated with increased frequency of appropriate corticosteroid administration, [15, 24] expedited corticosteroid administration, [13, 15] and decreased hospitalization rates, [13, 15, 25] ED LOS, [13, 26] prescribing errors [24] and return visits.[27] The duration of most these studies was only a few months. Moreover, none of these studies were performed in U.S. EDs. US EDs have shown great variability in asthma care and may be less willing to adapt pathways due to different constraints of the fee for service system, and lack of options for patient follow-up.[28] Our objective was to determine the effects of implementing an evidence-based clinical pathway on timely and appropriate administration of corticosteroids and bronchodilators, and imaging utilization and their subsequent effect on hospital admission for children with moderate-severe asthma exacerbations presenting to a general US ED.

METHODS

In this prospective cohort study we compared outcomes for patients managed by a clinical pathway (September 6, 2011 to September 6, 2013) with historical controls (January 1, 2006

to September 5, 2011), from the University of (institution name) ED. The Committee on Human Research at the University of (institution name) approved the study.

Setting

This is an urban, academic tertiary care ED with 33 beds and an annual census of approximately 34,000 adult and 6,000 pediatric patients serving an adult and children's hospital. Overall, about 16% of our patient population is black, 44% white (14% Hispanic or Latino), 15% Asian and 25% other race. Approximately 25% of pediatric patients are admitted to the hospital, 5% of these patients are admitted to the intensive care unit (ICU). Pediatric patients are seen by pediatric and emergency medicine residents, supervised 24 hours/7 days a week by attending physicians board eligible/board certified in emergency medicine who are salaried employees of the affiliated medical school. Nurse to patient ratio is 1:4 for all patients in treatment spaces. Triage acuity is assigned by trained triage nursing staff using the Emergency Severity Index (ESI) version 4, which uses a 5-tier scale, 1 being most acute.[29] Prior to the time of this study, the ED had no specific asthma protocols or pathways. All interventions (medications, diagnostic testing, and treatments) are physician-initiated. Residents' orders do not need an attending signature. Bedside nurses administer intermittent bronchodilator treatments based on a physician order. Respiratory therapists are only called to administer continuous bronchodilator treatments. None of these aspects of the setting changed at the time of pathway implementation.

Study Population

The study population consisted of patients ≥ 21 years of age with a moderate-severe asthma exacerbation defined as a visit where the primary ED diagnosis was asthma (International Statistical Classification of Diseases and Related Health Problems, Coordination and Maintenance (ICD-9-CM) code 493.xx) and the patient required ≥ 2 (or continuous) bronchodilator treatments (inhaled albuterol, albuterol-ipratropium, levalbuterol). [22] NIH guidelines recommend corticosteroids for all patients with asthma exacerbations except those with mild exacerbations who experience prompt relief with bronchodilator treatment. [2] Therefore, we excluded visits in which no more than one bronchodilator treatment was required. We also excluded patients who had received corticosteroids within 24 hours prior to their ED visit. We relied on the primary discharge diagnosis of asthma to exclude patients with bronchiolitis. All patients who presented to the ED during the study period and met the inclusion and exclusion criteria were included in the study (Figure 1).

Study Intervention

A multidisciplinary team including attending physicians and residents from Pediatrics and Emergency Medicine, and representatives from nursing, respiratory therapy and pharmacy produced a single page clinical pathway (Appendix 1) based on NIH asthma guidelines.[2] Previous studies, including one conducted at our institution, showed that delays in corticosteroid administration were associated with delayed bronchodilator treatment, hesitation about the youngest children, and fewer markers of severity, while only 1 in 8 chest radiographs (CXRs) affected treatment.[14, 22] The pathway targeted these areas by including clinical decision support tools for rapid assessment of exacerbation severity (Pediatric Asthma Score [2, 30]), response to treatment, and designation of the timing and

sequence of interventions for patients according to severity. The pathway reminded physicians that the NIH guidelines recommend CXRs in selected situations. To operationalize the NIH guidelines we used the mnemonic of the 4 F's, (fever, focal exam findings, concern for foreign body, and failure to improve) frequently used in lectures. The pathway also reminded providers that bacterial super-infection is rare in asthma and apparent infiltrates are often atelectasis. The pathway did not discuss other adjunctive therapies or include guidance regarding admission other than a statement consistent with the guidelines, which is to consider admission for patients whose symptoms did not resolve with treatment. [2]

Prior to pathway implementation, clinicians (nurses, respiratory therapists, attending and resident physicians) attended one of several 20 minute educational sessions led by the principle investigator (XX) to review the evidence-based guidelines. The educational sessions were conducted during regularly scheduled mandatory staff meetings, faculty meetings and resident teaching conferences to ensure wide dissemination. The guideline was also distributed to all providers by email. Clinicians were informed of the findings from previous retrospective studies at this institution along with the evidence for corticosteroid treatment in younger children[31] and those at the lower end of moderate severity,[11] and NIH guidelines for CXRs. [2] The pathway was posted in the ED at triage, in nurse and physician workstations, and included in the resident clinical handbook. During the first six months of implementation, research assistants identified pediatric asthma patients in the ED (Monday to Friday, 9am–5pm) and gave copies of the pathway to treating physicians and nurses. The pathway was also linked to the electronic pediatric ED asthma order set once the integrated electronic medical record (EMR) was implemented. Monthly email reminders were sent by the research assistant to treating clinicians when the pathway was not followed.

Data Source

Prior to June 2012, the ED used an internally developed, stand-alone EMR for triage information, physician documentation, and billing and charges. Physician orders and nursing notes (including times of medication administration) were documented on paper. Registration time, patient demographics, and disposition were recorded in the hospital's electronic registration database (GE Centricity™, Vacaville, CA). In June 2012, the hospital implemented an integrated EMR system (EPIC™, Verona, WI). Henceforth, all data were retrieved from the integrated EMR.

Data Collection

We identified all patient visits with a diagnosis of asthma (ICD-9-CM code 493.xx) during the study period through a search of the EMR and extracted data from discrete fields for time of arrival (time of registration), patient demographics, mode of arrival (self vs. ambulance), and triage data (presenting vital signs, triage acuity). In cases where data were missing or showed discrepancies, we reviewed the documentation in scanned paper documents or the EMR.

A research assistant identified charts meeting inclusion criteria. XX reviewed 15% of all charts for visits that did not meet the inclusion criteria with 100% agreement (kappa, 1). The

research assistant and XX reviewed all included charts together using a standardized data abstraction tool[32] for outcome measures, time from arrival to placement in a room, past medical history of asthma, use of supplemental oxygen, initial interpretation of CXRs, and other tests and medications ordered. Reasons for delays were inferred from the physician and nursing notes and ED timeline by XX and the research assistant and classified as likely attributable to delayed room placement, physician order, nurse administration or pharmacy issues, parental issues, and other. XX was responsible for training the research assistant and data verification. The research assistant met periodically with XX to resolve data entry discrepancies and review coding rules. Variables not present in the chart were labeled as missing data. The research assistant entered all data into an electronic spreadsheet (Microsoft Excel 2010; Microsoft Corporation, Redmond, WA). ED patient volume at the hour of patient arrival was extracted from a weekly registration report and added to the spreadsheet after completion of manual data abstraction.

The primary outcome measure was the percentage of visits that received corticosteroids in 60 minutes. Time to corticosteroid administration was calculated from the date and time of ED arrival to date and time of first corticosteroid administration. Although there is no standard definition for timely corticosteroid administration, 60 minutes was chosen based on prior studies and NIH guidelines. [2, 7, 15, 21, 22, 33] Time from ED arrival to corticosteroid administration was also analyzed as a continuous variable. Secondary outcome measures included omission of corticosteroids when indicated, timing of bronchodilators, use of CXRs. Other secondary outcomes were subsequent ED LOS and disposition (admission to inpatient bed, admission to ICU, discharge to home), as the pathway did not aim to directly impact these. ED LOS was measured from the time of ED arrival to ED discharge for patients who were discharged, as ED LOS for admitted patients often depended on hospital bed availability.

Predictor variables (Table 1) for delay and non-administration of corticosteroids were selected a priori based on clinical experience and results from previous studies.[19, 21, 22, 34–38] Tachypnea was defined as: >50 b/min for 3 months old; >40 b/min for 6 months old; >33 b/min for 9 months old; >30 b/min for 4 years old; >25 b/min for 8 years old; and >20 b/min for 8–21 years old.[39] ED patient volume at hour of arrival (a proxy for ED crowding) represented the total number of patients in the ED, including admitted patients waiting for an inpatient bed and those in the waiting room. [22, 36, 40, 41] Time of ED arrival was collapsed into two categories roughly reflecting variations in work shifts. Months of service were divided to capture any seasonal variations in peaks of asthma exacerbations.

Statistical Analysis

We compared the pre- (January 1st, 2006 to September 5th, 2011) and post-intervention (September 6th, 2011 to September 5th, 2013) periods. We chose this time span to gather a sample size sufficient to be able to detect approximately 7% difference (two-sided alpha 0.05 and beta 0.20) in the percentage of visits in which corticosteroids were delivered in 60 minutes (primary outcome). We followed measures two years after the intervention to determine sustainability of the change. We calculated descriptive statistics using proportions

for categorical measures, and means/standard deviations or medians/interquartile ranges (when distribution was not normal) for continuous measures. For the primary and secondary outcomes, we used univariate logistic regression models (Table 2) to examine whether odds of outcomes differed in the groups using generalized estimating equations (GEE, Proc Genmod in SAS). Clustering by medical record number was performed to control for multiple visits by a single patient. We developed multivariable logistic regression models to control for age, insurance, fever, tachypnea, time of arrival and ED patient volume at the hour of patient arrival. We developed separate multivariable logistic regression models for each outcome measure. A 2-tailed p value of <0.05 was considered significant. For continuous variables, we followed a similar procedure with univariate and multivariable log-gamma regression models (generalized linear models using a gamma distribution and a log link function) in order to account for the skewed distributions. We performed interrupted time series analysis by fitting separate linear trends to the data in the post-intervention and control periods to confirm that any change in the primary outcome measure was related to the intervention rather than overall unrelated trends. In addition, we developed multivariable logistic regression models to identify predictors of each outcome measure in the intervention period. Results for binary outcomes are expressed in adjusted odds ratios (ORs) and for continuous outcomes, adjusted rate ratios (RRs) with 95% Confidence Intervals (CIs). All analyses were performed using SAS statistical software (version 9.2, SAS Institute, Cary, NC).

RESULTS

A total of 1249 (870 pre- and 379 post-intervention) pediatric ED visits with moderate-severe asthma exacerbations were included. Baseline demographics and presenting characteristics were comparable between groups with a few exceptions (Table 1). The post-intervention group had a higher proportion of patients with tachypnea (73% vs 62%, $p < 0.01$) and a lower proportion of patients with fever (11% vs 17%, $p = 0.01$). The proportion of patients with Medicaid insurance and daytime presentation were also greater in the post-intervention period (55% vs 47%, $p = 0.04$ and 61% vs 46%, $p < 0.01$, respectively).

After controlling for differences between the pre and post-intervention groups, administration of corticosteroids within 1 hour of ED arrival (45% vs 18%, OR 3.5; CI 2.50–4.90) and overall corticosteroid administration occurred more frequently (96% vs. 78%, OR 6.35; CI 3.17–12.73) post-intervention (Table 3). Results were similar when time from ED arrival to corticosteroids was analyzed as a continuous variable. The proportion of visits with >1 bronchodilator dose received within 1 hour of ED arrival was higher (36% vs 24%, OR 1.65; CI 1.23–2.12) in the post-intervention group. CXRs were performed less often (27% vs 42%, OR 0.7; CI 0.52–0.94). Hospital admissions decreased in the post-intervention group (13% vs. 21%, OR 0.53; CI 0.37–0.76). ICU admission rate and ED LOS (for non-admitted patients) were unchanged.

Median time from ED arrival to corticosteroid administration decreased post-intervention (63 vs 108 min, $p < 0.001$ RR 0.74; 95% CI 0.67–0.81). When broken down into stages of care, median time from ED arrival to room placement decreased by 8 minutes (22 to 16 minutes, $p < 0.01$), room placement to corticosteroid order by 10 minutes (32 to 22 minutes,

$p<0.01$), and corticosteroid order to administration by 12 minutes (30 to 18 minutes, $p<0.01$).

The interrupted time series analysis confirmed that the improvement in the percentage of patients receiving corticosteroids within one hour of ED arrival was related to the intervention rather than overall unrelated trends (Figure 2). We estimated slopes pre- and post- pathway implementation for the percentage of patients receiving corticosteroids in within the first hour of ED arrival. This percentage was increasing 2% per year pre-pathway but 16% per year post-pathway and remained stable after EMR implementation.

In the post-intervention period, there was a delay in corticosteroid administration (> 60 minutes from ED arrival) in 55% of the visits ($n=208$). Delays in physician orders (49%), nurse administration (22%), and room placement (24%) were the most common reasons; one case was due to a pharmacy delay in obtaining the medication and three were due to documented initial refusal of the corticosteroid by the parents. The multivariate analysis within the post-intervention group, found that timely corticosteroid administration was associated with tachypnea (OR, 2.04; CI, 1.05–3.96) (Table 4). Patients were less likely to receive timely corticosteroids when ED volume was higher (OR, 0.97; CI, 0.94–0.99), compared with less crowded times, although the effect was small.

DISCUSSION

In our ED, implementing a clinical pathway based on NIH asthma guidelines was associated with improved asthma management for children with moderate-severe asthma exacerbations. The proportion of children receiving corticosteroids within 1 hour of ED arrival more than doubled and administration of corticosteroids took approximately 45 minutes (42%) less. While delays in room placement, bronchodilator administration, physician orders and nurse administration of corticosteroids persisted post-implementation, the pathway still improved overall timeliness in all of these steps. Overall, administration of corticosteroids, when indicated, increased by nearly a fifth and CXR use decreased by a third. Although the pathway was not designed to affect flow or admissions, the admission proportion decreased by nearly half after the pathway was implemented.

Our study confirms prior reports that clinical pathways can improve quality and efficiency of pediatric asthma care with the potential to improve patient outcomes. Two Canadian studies achieved a similar reduction in hospital admission rate (~50%) largely by expediting corticosteroid administration [13, 15]. And while these studies followed the effects of the pathways for only 2–4 months, we showed sustained benefits for 2 years. In addition, similar to other intervention studies outside the US, after pathway implementation, we were able to achieve 96% corticosteroid administration rate. [13, 15] This is much higher than the national average (63–69%) [17, 19] or rates reported in other single institution studies (83–85%).[14]

Unlike prior studies, we included patients less than 2 years of age or without prior history of asthma. The NIH guidelines for management of asthma exacerbation do not differentiate patients based on age or prior history of asthma.[2] In addition, the original randomized

controlled trials on the use of corticosteroids in asthma exacerbation included patients less than 2 years of age. [9, 10, 12] Young children are at high risk for severe exacerbations,[2] have the highest rate of ED asthma visits,[31] and are most likely to experience delayed corticosteroid treatment.[22] In our prior study, conducted between 2006 and 2011, age less than 2 years was associated with delay to corticosteroids. After pathway implementation, asthma treatment delays due to young age were eliminated.

We and others previously found that ED crowding was associated with delayed administration of corticosteroids for children with asthma exacerbation.[22, 33] In our prior study, crowding in our ED was associated with delay to steroids (OR, 0.79; 95% CI, 0.67–0.94). The current study shows that after pathway implementation, asthma treatment delays due to ED crowding were reduced. Perhaps, clinical pathways can decrease other consequences of ED crowding such as delays in antibiotic administration to febrile neonates and analgesic administration to pediatric patients with sickle cell pain crisis and fractures. [18, 42, 43] Clinical pathways not only appear to preserve quality of care during ED crowding; by improving efficiency and decreasing the number of patients waiting for hospital beds, they have the potential to reduce ED crowding.

Historically, our CXR utilization was high (42%), similar to national rates.[44] After pathway implementation, children were a third less likely to receive CXRs while the overall incidence of pneumonia co-diagnoses remained stable at approximately 5%. Although CXR utilization was a secondary outcome of the study, we found that a simple reminder was effective and likely beneficial. CXRs in the setting of pediatric asthma are of low yield and can be detrimental.[45] Judicious use can save time, reduce cost, improve patient safety, and limit unnecessary radiation and the risk of discovering and reacting to incidental findings.

Several inpatient pediatric asthma pathways have been studied in the US showing decreased hospital LOS, [30, 46–48] cost, [30, 46] and resource utilization, [49] and improved adherence with The Joint Commission's asthma measures [47] and other measures of quality of care.[30] By comparison, there are few ED pediatric asthma management systems or protocols that have been rigorously studied in the US.[50, 51] Dexheimer et al. developed a computerized asthma detection system for the early identification and treatment of patients with asthma exacerbations. However, the treatment protocol was 8 pages long and was underutilized. Krebs et al. developed a continuous nebulized albuterol protocol initiated by the triage nurse to expedite bronchodilator administration. However, delays persisted because nurses had to wait for respiratory therapists to administer the medication. Neither study focused on the use and timing of corticosteroids nor showed improved outcomes.

Our pathway did not impact ED LOS. Few pathways have been able to reduce ED LOS, [13, 26] while others have had no impact [15, 51]. The former institutions had much higher baseline ED LOS than us (6–8 hours vs under 4 hours, respectively) and perhaps more opportunity for improvement. Four hours was the cut-off used to decide disposition in the original randomized control studies evaluating the efficacy of corticosteroids [10, 12] and time needed to move from moderate-severe to mild status has been estimated to be approximately 3.5 hours.[13] Therefore, it may not be feasible to decrease ED LOS much

further as physicians need the time to monitor response to treatment. Shortening that time could in fact result in more admissions.

Gaps between current and best practices continue for the management of asthma for children in the US. ED providers are supportive and optimistic about successfully implementing an asthma pathway.[52] Our study suggests that a well-designed evidence-based standardized care plan can improve the quality, safety and efficiency of ED asthma care and prevent unnecessary hospital admissions. We believe our single-page pathway was easy to follow and translated the information in the NIH guidelines into a format more conducive to the needs of ED physicians. It urged quick assessment of severity, followed by immediate and (if needed) repeated bronchodilator treatments, and clear guidelines for corticosteroid administration and timing. The pathway targeted previous areas of delay (younger age, lower severity, and ED crowding),[22] reduced uncertainty and expedited corticosteroid administration. All members of the health care team were included in the education. Although all time intervals improved, physician orders of corticosteroids (especially for patients with less severe exacerbations) remained an important source of delay. A protocol allowing triage nurses to initiate corticosteroid treatment before physician assessment has proven successful in removing this barrier.[13]

Limitations

This is a single-center study in an urban, academic medical center providing tertiary pediatric care in a general ED. Thus, our findings may not be generalizable to other settings such as pediatric, rural or community EDs. However, almost 80% of pediatric patients with asthma receive care in general rather than pediatric EDs in the US [53]. In the absence of randomization, results may be biased due to unmeasured confounding and we can only report associations between the outcomes and predictor variables. The study design is strengthened by an interrupted time series analysis. While some of the initial improvement may be attributed to the Hawthorne effect (especially in the first 6 months when research assistants were reminding providers about the pathway), the improvement was sustained for two years making this less likely. The implementation of an integrated EMR occurred nine months after pathway implementation. It is possible that some of the improvement may be attributed to the integrated EMR. However, our time series analysis shows that the improvement started with pathway implementation. We were not able to measure ED returns; however, others have shown that asthma pathways are not associated with increased ED returns [25] and may even decrease ED returns.[27] In addition, other studies achieving similar reductions in ED CXR use have shown that, of the patients who did not have a CXR in the ED, none had an abnormal CXR obtained after admission or if they returned to the ED within 72 hours.[54] If pre-ED inhaled corticosteroid (ICS) use increased over time in our population, there is a possibility that this could have decreased admission proportions. However, this is unlikely because we controlled for severity of illness on presentation. The pathway did not include specific recommendations for administering bronchodilator by metered dose inhaler for moderate exacerbations as this is often difficult in young children and those with more severe exacerbations. We also did not address magnesium sulfate or ICS in the ED. Future pathways may consider including these and other adjunctive therapies. A standardized data abstraction tool containing clear definitions was used by the

two reviewers to collaboratively collect data variables, which were objective and did not require interpretation. Therefore, agreement/kappa statistics were performed only for determination of visit inclusion. Finally, we did not collect the route of corticosteroid administration. Following NIH guidelines, the preferred route of corticosteroid administration in our ED has been oral. In general, only children who could not tolerate oral medications (i.e., severely ill) received intravenous administration. The proportion of severely ill children was the same in the pre and post-pathway period so we do not expect differences in timeliness of corticosteroids to be due to differences in the route of administration.

In conclusion, we found that implementing an evidence-based clinical pathway was associated with a doubling of the receipt of corticosteroids within 1 hour of ED arrival and a subsequent reduction in the hospital admission proportions by half in children with moderate-severe asthma exacerbations presenting to a general academic ED. If widely adopted, this strategy could improve the quality, safety and efficiency of asthma care, and have a significant impact on the burden of asthma in U.S. EDs and hospitals.

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Appendix 1. Pediatric Asthma Pathway

Figure 1.
Flow diagram for total patients included in the study.

Figure 2.
Proportion receiving corticosteroids within one hour of ED arrival.

Table 1

Characteristic data for patients seen in the ED with moderate-severe asthma exacerbation (n = 1249).

	Pre-pathway n=870	Post-pathway n=379	p Value
Age (%)			
<24 months	24	19	0.051
2–5 years	41	41	
6–12 years	22	28	
13–21 years	13	12	
Sex (%)			
Male	64	67	0.42
Race/ethnicity* (%)			
White	23	23	0.16
Black	25	22	
Hispanic	15	19	
Asian	23	21	
Other	14	15	
Insurance [†] (%)			
Private	48	42	0.036
Medicaid	47	55	
Other	5	3	
Triage (%)			
1	1	1	0.062
2	25	20	
3	54	55	
4/5	20	24	
Arrival by Ambulance (%)	3	2	0.32
Past history of asthma (%)	78	80	0.41
Fever (>38.0°C) on presentation (%)	17	11	0.01
Tachypnea (%)	62	73	<0.001
Hypoxia (oxygen saturation < 93%, %)	13	12	0.49
Pneumonia, secondary diagnosis (%)	5	5	0.98
Receipt of supplemental oxygen (%)	13	11	0.36
Receipt of antibiotics (%)	9	9	0.79
Bronchodilators (mean)	3	3	0.15
ED patient volume at hour of arrival (mean)	29	29	0.73
Time of arrival (%)			
Day (7am–7pm)	46	61	<0.001
Night (7pm–7am)	54	39	
Season of service (%)			

	Pre-pathway n=870	Post-pathway n=379	p Value
Fall	28	27	0.21
Winter	28	33	
Spring	25	24	
Summer	19	16	

P values less than 0.05 are in bold.

* self-reported.

[†] private (non-government), other (e.g., self-pay, no charge/charity).

Table 2

Univariate Logistic Model post-pathway implementation.

	Pre-pathway N=870	Post-Pathway N=379	Odds Ratio	Confidence Interval
Corticosteroids (%)	78.3	95.5	5.90	3.50, 9.80
Corticosteroids within 1 hour (%)	18.3	45.1	3.70	2.80, 4.80
Arrival to corticosteroids (median, IQR, min)	108 (65,163)	63 (44,96)	(p<0.001)	
Bronchodilator, 3 doses in 1 st hour (%)	5.1	8.2	1.67	1.03, 2.70
Bronchodilator, >1 doses in 1 st hour (%)	23.9	36.4	1.82	1.40, 2.40
Bronchodilators in 1 st hour (mean $\pm$ SD)	0.98 (0.84)	1.16 (0.94)	(p=0.002)	
Chest radiograph (%)	41.8	27.4	0.53	0.40, 0.68
Hospital Admission (% , excluding visits without steroids)	21.0	13.3	0.58	0.40, 0.82
ED length of stay (median, IQR, min, excluding admissions)	209 (162,269)	204 (143,287)	(p=0.27)	
ICU Admission (%)	2.7	4.1	1.50	0.55, 4.09

SD, Standard Deviation.

Odds Ratios in bold are significant.

Table 3

Multivariable Logistic Model post-pathway implementation.

	Adjusted Odds Ratio	Confidence Interval
Corticosteroids	6.35	3.17, 12.73
Arrival to corticosteroids	0.74*	0.67, 0.81
Corticosteroids within 1 hour	3.50	2.50, 4.90
Bronchodilator, 3 doses in 1 st hour	1.32	0.71, 2.45
Bronchodilator, >1 doses in 1 st hour	1.65	1.23, 2.21
Bronchodilators in 1 st hour	1.11*	0.98, 1.26
Chest radiograph	0.70	0.52, 0.94
ED length of stay (excluding admissions)	1.00*	0.94, 1.05
Hospital Admission (excluding visits without steroids)	0.53	0.37, 0.76

Odds Ratios and *Rate ratio in bold are significant. Adjusted for age group, fever, insurance, tachypnea, time of arrival, and ED patient volume at the hour of patient arrival.

Table 4

Likelihood of receiving corticosteroids within one hour of ED arrival (multivariable regression). Post-pathway group only.

	Adjusted Odds Ratio	Confidence Interval
Age		
<24 months	0.62	0.23, 1.67
2–5 years	1.27	0.54, 2.96
6–12 years	1.12	0.45, 2.81
13–21 years	1	(ref)
Fever (yes vs. no)	0.78	0.32, 1.92
Tachypnea (yes vs. no)	2.04	1.05, 3.96
ED patient volume at hour of arrival	0.97*	0.94, 0.99
Time of arrival (7pm–7am vs. 7am–7pm)	1.24	0.71, 2.17

Odds Ratios and *Rate ratio in bold are significant.