A Report of an Asthma Pathway Leading to Improved Resource Use

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OBJECTIVES Asthma pathways have been shown to improve resource use and decrease length of stay (LOS). A tertiary care hospital implemented an asthma pathway in May 2015 to standardize inpatient care. We predicted that the pathway would increase the use of albuterol metered-dose inhalers (MDIs) and steroids; decrease use of albuterol nebulizer, antibiotics, chest radiograph (CXR), and respiratory viral panel (RVP); and decrease LOS.

METHODS This retrospective cohort study selected patients between the ages of 2 and 18 years who were admitted for asthma as a primary diagnosis between May 2014 and May 2016 (1 year preimplementation to 1 year postimplementation). Patients' complex chronic conditions were excluded. We analyzed use of albuterol nebulizer, MDI, and continuous nebulization, ipratropium bromide, oral steroids, antibiotics, inhaled steroids, CXR, and RVP. We also evaluated LOS and readmission rate.

RESULTS There were 1131 and 925 patients identified before and after asthma pathway implementation, respectively. The percent that received albuterol nebulizer decreased from 14.1% to 6.1% ($p < 0.001$). The percent that received albuterol MDI increased from 97.0% to 99.4% ($p < 0.001$). The average number of MDI administrations decreased from 11.6 to 10.4 ($p = 0.004$). Continuous albuterol use increased from 52.3% to 59.1% ($p = 0.002$). There was no change in ipratropium bromide, oral steroid, inhaled steroid, or CXR use. Antibiotic ($p = 0.049$) and RVP ($p = 0.03$) use decreased. The average LOS decreased from 1.84 days to 1.71 days ($p = 0.02$). Readmission rates did not change significantly.

CONCLUSIONS The asthma pathway improved inpatient albuterol MDI use. The LOS decreased while maintaining readmission rates.

ABBREVIATIONS CXR, chest radiograph; ED, Emergency Department; LOS, length of stay; MDI, metered-dose inhalers; RVP, respiratory viral panel

KEYWORDS albuterol; asthma pathway; MDI; nebulizer; resource use

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Introduction

In the current health care climate, there is a strong emphasis on providing high-quality care while decreasing costs.^{1,2} Choosing Wisely is a campaign led by the American Board of Internal Medicine that aims to reduce unnecessary testing and treatment. The campaign asked the leading medical societies to choose 5 tests, procedures, or treatments that are overused in their specialty.³ A total of 70 medical societies have contributed more than 400 recommendations, many of which have been published in the literature.⁴ For uncomplicated asthma exacerbations, the National Heart, Lung and Blood Institute (NHLBI) and the Choosing Wisely campaign recommend against the routine use of chest radiograph (CXR) and the routine use of antibiotics, and the National Heart, Lung and Blood Institute recommends limiting ipratropium bromide use to the first 24 hours.^{3,5,6} However, variation still exists in the treatment of asthma.⁷ Among 42 hospitals, a median

of 46% of uncomplicated asthma cases used CXR, 16% used antibiotics, and 7.8% used ipratropium bromide after the first day of admission.⁷

Locally, hospitalization rates in Chicago have been shown to be more than twice as high as rates in the United States.⁸ A multidisciplinary team from a tertiary care hospital launched a care pathway for the treatment of asthma exacerbations in May 2015. The care pathway implemented an order set, an admission note, and a nurse and respiratory therapist–driven weaning algorithm. The order set listed metered-dose inhalers (MDIs) as the preferred route of albuterol administration, but it allowed for continuous nebulization in severe asthma exacerbations. The routine use of albuterol via nebulizer was discouraged. The weaning algorithm outlined how often nurses and respiratory therapists should assess patients, and the protocol for weaning or intensifying treatment. In this algorithm, albuterol MDI dosing was increased from the usual practice standard, such that patients less than 20 kg were increased from

2 to 4 puffs to 4 to 6 puffs, and patients more than 20 kg were increased from 4 to 6 puffs to 6 to 8 puffs per administration (each puff contains 90 mcg of albuterol base). Continuous albuterol dosing was also increased and was administered to patients with a high asthma score; patients less than 20 kg received 10 mg/hr, whereas those ≥ 20 kg received 15 mg/hr.

Several studies have shown reductions in length of stay (LOS)⁹ and cost after asthma pathway implementation.^{10,11} Some have also reported the effects on resource use, particularly with albuterol in the inpatient setting.^{11–14} The purpose of this study was to examine the effect of the asthma pathway on a wider range of resources: albuterol administration (MDI vs. nebulizer), steroids, antibiotics, CXR, and respiratory viral panel (RVP) use at our institution. We predicted that the pathway would increase the use of albuterol MDI and steroids; decrease use of albuterol nebulizer, antibiotics, CXR, and RVP; and decrease LOS.

Methods

Study Population. This retrospective cohort study selected patients between the ages of 2 and 18 years who were admitted to the observation unit, inpatient floor, and pediatric intensive care unit for asthma as a primary diagnosis (ICD-9 CM 493/ICD-10 CM J45 or APR-DRG of 141) between May 2014 and May 2016 (1 year preimplementation to 1 year postimplementation). Patients were excluded if they had active cardiac disease, airway abnormalities, allergic bronchopulmonary aspergillosis within 6 months, bronchiolitis, bronchopulmonary dysplasia, pneumonia with effusion, cystic fibrosis, neuromuscular disease, and tracheostomy dependence.

Data Collection. This retrospective cohort study was approved by the hospital's Institutional Review Board. A primary report consisted of data obtained through the electronic medical record for patients who met inclusion and exclusion criteria. Data included hospital account number, length of stay, readmission, and relevant demographics. A second report was created by the pharmacy department on all charges and nursing administrations for all patients receiving medications under analysis. This pharmacy report was cross-referenced to the primary report to build a resultant pharmacy report for patients meeting inclusion and exclusion criteria.

Two chart reviews were completed. The first was a chart review for each patient who received antibiotics throughout the study period as identified on the pharmacy charge report. Patients who were given antibiotics for anti-inflammatory effects versus all other reasons were captured. The second chart review was done on a subpopulation of the cohort admitted during peak asthma season, September through November of 2014 and 2015, to determine inhaled steroid, CXR, and RVP use. Chart review was necessary because the data were not readily available from the pharmacy reports.

A subpopulation was chosen to avoid chart reviewing the entire cohort. When reviewing inhaled steroids, it was first determined in the chart review if there was clinical need for this medication (e.g., persistent asthma or other documentation detailing need). This determination was validated by a Pediatric Hospitalist (an Asthma Team member). For those patients requiring inhaled steroids, both the inpatient and discharge medication lists were evaluated for inclusion of inhaled steroids. The chart review for CXR stratified patients by whether they had pneumonia on the radiographic report.

Data Analysis. We compared the percent of patients who received the following prepathway and postpathway: albuterol nebulizer, albuterol MDI, continuous albuterol nebulization, ipratropium bromide (MDI or nebulizer) after the first, second, and third days of admission, oral steroids, antibiotics, inhaled steroids, CXR, and RVP. Patients who had received oral steroids in the Emergency Department (ED) were included. Albuterol was further stratified by patients who only received albuterol nebulizers (no MDI) and patients who only received albuterol MDI (no routine nebulization); these groups included patients who could have received continuous albuterol. We calculated the average number of nursing administrations of albuterol MDI for those who received it prepathway and postpathway. We calculated the average time patients were on continuous albuterol nebulization by multiplying the number of continuous administrations by the length of time for each administration (4 hours). Finally, we measured demographic data using age, sex, race, ethnicity, and insurance as a proxy for socioeconomic status to assess for similarity between the pre and post populations. We evaluated LOS as outcome measures, and readmission rate as a balancing measure.

Statistical Analysis. The χ^2 test was used to compare the proportion of patients that received a resource and to assess race, ethnicity, and insurance proportions. The Wilcoxon rank sum test and the 2-sided unpaired *t*-test was used to compare average number of medication administrations, average time on continuous, and average LOS. All analysis was performed using Microsoft Excel (Redmond, WA). A *p* value <0.05 was considered significant.

Results

There were 1131 patients identified preimplementation and 925 patients identified postimplementation who fit our cohort. Comparison of their demographic information is summarized in Table 1. Average ages of the pre and post cohorts were 6.42 and 6.44 years (*p* = 0.92), respectively. There were no significant differences in proportions of sex, race, or ethnicity. The post group had a higher proportion of patients with public insurance and lower proportion with private insurance (*p* = 0.008).

Resource use results are summarized in Table 2.

Table 1. Comparison of Population Demographics Before (N = 1131) and After (N = 925) Asthma Pathway Implementation

	Before	After	p value
Age, yr, mean (95% CI)	6.42 (6.20–6.64)	6.44 (6.19–6.68)	0.92
Male sex, n (%)	707 (62.51)	575 (62.16)	0.87
Race, n (%)			0.25
White	232 (20.51)	162 (17.51)	
Black/African American	387 (34.22)	309 (27.32)	
American Indian/Alaskan native	2 (0.18)	1 (0.11)	
Asian	37 (3.27)	23 (2.49)	
Other	456 (40.32)	420 (45.41)	
Unknown	14 (1.24)	9 (0.97)	
Declined	3 (0.27)	1 (0.11)	
Ethnicity, n (%)			0.16
Not Hispanic or Latino	649 (57.38)	488 (52.76)	
Hispanic/Latino	463 (40.94)	424 (45.84)	
Unknown	17 (1.5)	11 (1.19)	
Declined	2 (0.18)	2 (0.22)	
Insurance, n (%)			0.008
Public	776 (68.61)	689 (74.49)	
Private	345 (30.5)	227 (24.54)	
Government	1 (0.09)	4 (0.43)	
Unknown	9 (0.8)	5 (0.54)	

The percent of patients that received any albuterol nebulizer decreased from 14.1% to 6.1% ($p < 0.001$). The percent that received only albuterol nebulizer (no MDI) decreased from 2.6% to 0.1% ($p < 0.001$). The percent that received any albuterol MDI increased from 97.0% to 99.4% ($p < 0.001$). The percent that received only albuterol MDI (no nebulizer) increased from 85.5% to 93.4% ($p < 0.001$). The percent that received both MDI and nebulizer decreased from 11.5% to 5.9% ($p < 0.001$). Of the patients who only received albuterol MDI, the average number of MDI administrations decreased from 11.6 to 10.4 administrations ($p = 0.004$; Figure 1). The percent that received inpatient continuous albuterol increased from 52.3% to 59.1% ($p = 0.002$). The average time on continuous albuterol did not change significantly.

There was no significant change in ipratropium bromide use on the first, second, and third day of admission. There was no change in the percent of patients who received oral steroids or inhaled steroids. Of all the patients without pneumonia, the percent that got a CXR did not change significantly from 16.6% to 17.9% ($p = 0.63$). Of the people who got a CXR, 89% were determined not to have pneumonia in both pre and post years ($p = 0.95$). The percent of patients that received antibiotics for anti-inflammatory effects

decreased from 1.4% to 0.5% ($p = 0.049$). Use of RVP decreased from 8.2% to 4.3% ($p = 0.03$). The average LOS decreased from 1.84 days to 1.71 days ($p = 0.02$), which is a difference of 3.12 hours (Figure 2). However, the median LOS, calculated using the rank sum test, did not change significantly from 1.46 to 1.42 days ($p = 0.13$). The 7-day and 30-day readmission rates did not change significantly—from 1.2% to 0.97% ($p = 0.57$) and 3.1% to 3.7% ($p = 0.47$), respectively.

Discussion

This study demonstrates an asthma pathway that was successful in decreasing routine inpatient nebulization, increasing MDI use, and adhering to guidelines for steroid use. Although nebulizer use was already low, there was a decrease in the percentage of patients who received both nebulizer and MDI, from 11.5% to 5.9%. This finding suggests that patients were started directly on albuterol via MDI from their continuous albuterol, rather than being started on a nebulizer and switched to MDI closer to discharge. This result is expected because the pathway used an order set that prioritized MDI over nebulization. Use of oral steroids and inhaled steroids showed adherence to the guidelines that all patients should receive oral steroids and patients with persistent asthma need a controller. Both systemic and

Table 2. Comparison of Resource Use Before and After Asthma Pathway Implementation

Resource Name	Asthma Pathway Implementation				p value
	Before		After		
	n (%)	N	n (%)	N	
Albuterol					
Albuterol nebulizer*	159 (14.1)	1131	56 (6.1)	925	<0.001
Only albuterol nebulizer†	29 (2.65)	1131	1 (0.1)	925	<0.001
Albuterol MDI‡	1097 (97)	1131	919 (99.4)	925	<0.001
Only albuterol MDI§	967 (85.5)	1131	864 (93.4)	925	<0.001
Nebulizer and MDI	130 (11.5)	1130	55 (5.9)	925	< 0.001
Albuterol MDI, administrations (total) [95% CI] ¶#	11.6 (11,224) [11.1–12.1]	967	10.4 (8986) [10.0–10.8]	864	0.004
Continuous albuterol	592 (52.3)	1131	547 (59.1)	925	0.002
Time on continuous, hr (total) [95% CI]#	15.6 (9920) [14.4–16.8]	592	15.2 (8328) [14.0–16.4]	547	0.87
Ipratropium bromide					
≥0 days	103 (9.1)	1131	85 (9.2)	925	0.95
≥1 day	80 (7.5)	1072	73 (8.2)	888	0.48
≥2 days	41 (7.6)	543	42 (9.7)	435	0.29
Steroids					
Oral	1118 (98.9)	1131	913 (98.8)	925	0.93
Inhaled	335 (98.5)	340	238 (98.8)	241	0.82
Antibiotics (oral and/or intravenous)	16 (1.45)	1131	5 (0.5)	925	0.049
CXR					
CXR used**	79 (16.6)	477	57 (17.9)	319	0.63
Negative CXR rate††	79 (88.8)	89	57 (89)	64	0.95
RVP	40 (8.2)	487	14 (4.3)	326	0.03
LOS, days [95% CI]#	1.84 [1.77–1.93]	1131	1.71 [1.64–1.79]	925	0.02
Readmission					
Within 7 days	14 (1.2)	1131	9 (0.97)	925	0.57
Within 30 days	35 (3.1)	1131	34 (3.7)	925	0.47

CI, confidence interval; CXR, chest radiograph; LOS, length of stay; MDI, metered-dose inhaler; RVP, respiratory viral panel

* Received any albuterol nebulizer.

† Received albuterol nebulizer but did not receive any MDI.

‡ Received any albuterol MDI.

§ Received albuterol MDI but did not receive any nebulizer.

¶ Average number of administrations given to those who only received MDI and did not receive any nebulizer.

Albuterol MDI administrations, hours on continuous albuterol, and LOS are reported as averages and not percentages.

** Percent that got a CXR, of all patients who did not have pneumonia.

†† Percent that had no radiologic evidence of pneumonia, of the patients who got a CXR.

inhaled steroids were part of the new admission note.

Replacing nebulizers with MDI and spacer has been shown to decrease LOS in the ED¹⁰ and inpatient settings.¹³ Previous asthma interventions have also found order sets¹¹ and nurse-driven weaning protocols¹⁴ to decrease the number of bronchodilator (nebulizer) treatments and to decrease LOS. In our study, pathway implementation was associated with a decrease

in the number of MDI treatments by 1.2 treatments, a decrease in average LOS by 0.13 days, and a non-significant decrease in median LOS. The fact that the average LOS was significant, but the median was not, suggests that the pathway decreased LOS for patients at the extremes but not for the typical patient, because outliers have a greater effect on the mean. A 2011 retrospective study that replaced routine nebulization with

Figure 1. Average number of administrations given to those who received albuterol via metered-dose inhaler.* Error bars represent 95% confidence interval.

* These patients did not receive albuterol via nebulization but may have received it via continuous administration.

MDI showed a decrease in LOS by 0.41 days.¹³ A study that implemented an asthma order set and pathway showed a decrease in LOS by 0.45 days and reduction in hospitalization cost from \$2010 to \$1174 per patient.¹¹ Our reduction in LOS was not as dramatic as those found in these other studies, but the resources saved from switching from nebulizers to MDI are likely still clinically significant. Although the unit cost of an MDI is higher than that of a nebulizer, the potential decrease in resources used from switching to MDI likely reduces overall health system costs. Although a decrease in MDI administrations by 1.2 treatments would not change the number of MDI units dispensed by the pharmacy department, 1 fewer MDI treatments could save a patient between 2 and 4 hours in the hospital, and thus shorten LOS. Administering nebulized doses of albuterol also takes significantly longer than administering an MDI, which ties up important hospital resources, like nursing and respiratory therapists. Our results showed a significant decrease in nebulizer use from 14.1% to 6.1% and interestingly did not see a corresponding increase in the number of MDI administrations. These findings suggest that our pathway decreased hospital resources needed to administer these medications.

The decrease in LOS is likely due to the pathway, a combination of increased use of MDIs, increased MDI dosing, and the nurse-driven or respiratory therapist-driven weaning protocol. Although our intervention increased MDI dosing, studies have shown conflicting results about whether there is clinical benefit to using a larger dose of albuterol.^{15–17} A 2016 randomized trial

Figure 2. Average length of stay. Error bars represent 95% confidence interval.

compared large-dose albuterol to small dose in children with moderate to severe asthma in the ED and found no significant differences in LOS, admission rate, and safety profile.¹⁵ Another study comparing a single, large dose (6–10 puffs) of albuterol to small dose (2 puffs) in children with mild acute asthma showed a non-significant larger improvement in forced expiratory volume in 1 second for the large-dose group.¹⁶ The authors suggested that if the sample size was larger and the patients had more severe asthma, they may have detected a difference. Finally, a study in 11 adults with severe acute asthma showed dose-related improvement in forced expiratory volume in 1 second during the course of receiving 4 puffs every 10 minutes for 3 hours.¹⁷ In our study, the shortened LOS did not increase readmission rates, meaning that patients still received quality care and were discharged in a stable condition. Future projects in quality improvement at this hospital should focus on switching over to MDI in the ED setting, because this has not been done yet. Studies have shown this process change can decrease readmission rates,¹³ and LOS in the ED.¹⁰

A quality improvement study from 2014 listed 3 achievable benchmarks of care for pediatric hospitals to improve management of uncomplicated asthma.⁷ These were: reducing ipratropium bromide use after the first day of admission to 2.4%, antibiotics to 16%, and CXRs to 25%.⁷ Our asthma initiative addressed antibiotics, CXR, and RVP by excluding antibiotics and RVP from the order set and pathway, and CXR from the pathway. In evaluating our results, ipratropium bromide use did not decrease with the care pathway, and further interventions and study are warranted. This result was expected because the pathway did not ad-

dress ipratropium use. Antibiotic use decreased, and both preuse and postuse rates were below 1%. Use of CXR also remained below the achievable benchmark of care at 17%. Interestingly, only 11% of CXRs done in our patient population detected a pneumonia. Bekmeziyan et al¹⁸ also found that about 1 in 8 CXRs in patients with moderate to severe asthma detected a pneumonia. They implemented an intervention in the ED to reduce CXRs and to only order 1 if a patient had focal findings, fever, foreign body concern, and failure to improve. They decreased the number of CXRs from 43% to 27%.¹² Finally, our results showed a significant decrease in the use of RVP postpathway implementation, suggesting that future asthma initiatives should exclude RVP from asthma order sets and pathways. Future efforts should be done to limit ipratropium bromide to the first day of admission and to further reduce CXR use in the ED.

One strength of the study was capturing 2 years of data, which helped account for seasonal variations of asthma severity both preintervention and postintervention. In addition, the large sample size of each year increased the power of the study. This study had several limitations. It was a retrospective cohort study, so it could only demonstrate association. The populations did not come from the same time frame but compared 1 year before and after implementation. This has the potential to introduce confounders that make the populations different and influence the resource use. For example, the postimplementation period had a higher proportion of patients who received public aid. However, a study from the United Kingdom found that variation in inpatient LOS was not consistently explained by socioeconomic status.¹⁹ In addition, the asthma severity of each patient was not pulled from the electronic health record, so one population might have had more patients with severe asthma, which could affect the number of MDI administrations a patient received. Another limitation was that the pathway was multifactorial, so we cannot be certain as to which part of the pathway had the greatest influence on our results. Future multivariate analysis can elucidate the factors that decreased the MDI administrations and LOS. Finally, our data were only as accurate as the pharmacy charge reports, nursing administration reports, and what was documented in the chart. However, pharmacy charge reports are close to what a patient received in the hospital, and the chart review was double checked by an asthma team member.

Conclusion

This study has added to the literature by showing a case example of an asthma pathway improving albuterol use and decreasing LOS while maintaining use of achievable benchmarks of care at the level of high performers. Further study is needed to evaluate methods to decrease ipratropium bromide after 24 hours of admission and improve CXR use in the ED.

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REFERENCES

1. Obama B. United States health care reform progress to date and next steps. *JAMA*. 2016;316(5):525–532.
2. Cowing M, Davino-Ramaya CM, Ramaya K, Szmerekovsky J. health care delivery performance: service, outcomes, and resource stewardship. *Perm J*. 2009;13(4):72–78.
3. Quinonez RA, Garber MD, Schroeder AR, et al. Choosing wisely in pediatric hospital medicine: five opportunities for improved healthcare value. *J Hosp Med*. 2013;8(9):479–485.
4. ABIM Foundation. Choosing wisely. <http://abimfoundation.org/what-we-do/choosing-wisely>. Accessed May 19, 2018.
5. Society of Hospital Medicine. Don't order chest radiographs in children with uncomplicated asthma or bronchiolitis. <http://www.choosingwisely.org/clinician-lists/society-hospital-medicine-pediatric-chest-radiographs-for-uncomplicated-asthma-bronchiolitis/>. Accessed May 19, 2018.
6. Wolfson D, Santa J, Slass L. Engaging physicians and consumers in conversations about treatment overuse and waste: a short history of the choosing wisely campaign. *Acad Med*. 2014;89(7):990–995.
7. Parikh K, Hall M, Mittal V, et al. Establishing benchmarks for the hospitalized care of children with asthma, bronchiolitis, and pneumonia. *Pediatrics*. 2014;134(3):555–562.
8. Thomas SD, Whitman S. Asthma hospitalizations and mortality in Chicago: an epidemiologic overview. *Chest*. 1999;116(suppl 2):135S–141S.
9. Edwards E, Fox K. A retrospective study evaluating the effectiveness of an asthma clinical pathway in pediatric inpatient practice. *J Pediatr Pharmacol Ther*. 2008;13(4):233–241.
10. Cates CJ, Welsh EJ, Rowe BH. Holding chambers (spacers) versus nebulisers for beta-agonist treatment of acute asthma. *Cochrane Database Syst Rev*. 2013;13(9):Cd000052.
11. Dayal A, Alvarez F. The effect of implementation of standardized, evidence-based order sets on efficiency and quality measures for pediatric respiratory illnesses in a community hospital. *Hosp Pediatr*. 2015;5(12):624–629.

12. Bekmezian A, Fee C, Weber E. Clinical pathway improves pediatrics asthma management in the Emergency Department and reduces admissions. *J Asthma*. 2015;52(8):806–814.
13. Goh AE, Tang JP, Ling H, et al. Efficacy of metered-dose inhalers for children with acute asthma exacerbations. *Pediatr Pulmonol*. 2011;46(5):421–427.
14. Johnson KB, Blaisdell CJ, Walker A, Eggleston P. Effectiveness of a clinical pathway for inpatient asthma management. *Pediatrics*. 2000;106(5):1006–1012.
15. Muchão FP, Souza JMe, Torres HCC, et al. Albuterol via metered-dose inhaler in children: lower doses are effective, and higher doses are safe. *Pediatr Pulmonol*. 2016;51(11):1122–1130.
16. Schuh S, Johnson DW, Stephens D, et al. Comparison of albuterol delivered by a metered dose inhaler with spacer versus a nebulizer in children with mild acute asthma. *J Pediatr*. 1999;135(1):22–27.
17. Rodrigo C, Rodrigo G. High-dose MDI salbutamol treatment of asthma in the ED. *Amer J Emer Med*. 1995;13(1):21–26.
18. Bekmezian A, Fee C, Bekmezian S, et al. Emergency Department crowding and younger age are associated with delayed corticosteroid administration to children with acute asthma. *Pediatr Emer Care*. 2013;29(10):1075–1081.
19. Heys M, Rajan M, Blair M. Length of paediatric inpatient stay, socio-economic status and hospital configuration: a retrospective cohort study. *BMC Health Serv Res*. 2017;17:274.