RESEARCH ARTICLE

A Clinical Pathway for the Care of Critically Ill Patients With Asthma in the Community Hospital Setting

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ABSTRACT

OBJECTIVES: The management of severe pediatric asthma exacerbations is variable. The use of clinical pathways has been shown to decrease time to clinical recovery and length of stay (LOS) for critically ill patients with asthma in freestanding children's hospitals. We sought to determine if implementing a clinical pathway for pediatric patients who are on continuous albuterol in a community hospital would decrease time to clinical recovery and LOS.

METHODS: A clinical pathway for guiding the initiation, escalation, and weaning of critical asthma therapies was adapted to a community hospital without a PICU. There were 2 years of baseline data collection (from September 2014 to August 2016) and 16 months of intervention data collection. Segmented regression analysis of interrupted time series was used to evaluate the pathway's impact on LOS and time to clinical recovery.

RESULTS: There were 129 patients in the study, including 69 in the baseline group and 60 in the intervention group. After pathway implementation, there was an absolute reduction of 10.2 hours (SD 2.0 hours) in time to clinical recovery ($P \leq .001$). There was no significant effect on LOS. There was a significant reduction in the transfer rate (27.5% of patients in the baseline period versus 11.7% of patients in the intervention period; $P = .025$). There was no increase in key adverse events, which included the percentage of patients who required ICU-specific therapies while awaiting transfer (7.3% of patients in the baseline period versus 1.7% of patients in the intervention period; $P = .215$).

CONCLUSIONS: The implementation of a clinical pathway for the management of critically ill children with asthma and on continuous albuterol in a community hospital was associated with a significant reduction in time to clinical recovery without an increase in key adverse events.

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Given the prevalence of pediatric asthma and the costs associated with inpatient admission, improving clinical outcomes in children who are hospitalized with asthma has been an area of considerable research.[1–3] The use of inpatient asthma pathways has been shown to decrease length of stay (LOS) and the overuse of unnecessary clinical therapies.[4–10] Although much of the research on inpatient pathways has taken place in freestanding children's hospitals, at least 1 study in a community hospital reveals similar improvement in outcomes.[11] Although the use of these pathways has increased in recent years, providers at community hospitals are significantly less likely to use clinical pathways.[12]

There is considerable variation in the management of patients with severe asthma exacerbations.[13] Patients with critical asthma can be defined as admitted patients who require continuous albuterol via a nebulizer (CAN). With the establishment of the safety and efficacy of CAN,[14,15] critical asthma pathways often support a stepwise escalation to augmentative therapies including magnesium, heliox, terbutaline, and noninvasive ventilation.[16] However, there remains some uncertainty about how and when to initiate these augmentative therapies, and limited data about their efficacy exist.[17,18] In a 2017 study, Wong et al[19] showed a reduction in the length of time on continuous albuterol using a stepwise approach to therapy escalation driven by an asthma severity score. A subsequent iteration of that pathway resulted in a significant decrease in LOS and time to albuterol administered every 4 hours (q4h), which is a proxy of clinical recovery and discharge readiness.[20]

This growing body of evidence for the management of critical asthma has come out of freestanding children's hospitals. However, a 2010 survey of >28 000 patients with severe asthma exacerbations revealed that the majority of these patients are admitted to community hospitals without a PICU.[21] We are not aware of any study in which the implementation of an asthma pathway for critical asthma in the community hospital setting is assessed.

Our aim in this study was to assess whether the implementation of a critical asthma pathway (as adapted from Wong et al[19]) would safely decrease time to clinical recovery and hospital LOS in a community hospital without a PICU.

METHODS

This was a quality-improvement intervention in which we used historical controls in the pediatric unit at a community hospital.

Context

This community hospital has a 16-bed pediatric inpatient unit within the 387-bed hospital. It is affiliated with a large, freestanding children's hospital, which is located 17 miles away in Boston (30–100 minutes via car). The 12-person pediatric hospitalist group is employed by the affiliated freestanding children's hospital. There are 1 to 2 pediatric hospitalists covering the inpatient unit at all times.

Nurse staffing in the unit is 4 patients to every nurse. However, for critically ill patients (ie, the patients on continuous albuterol in this study), the nurses are staffed at a 1:2 ratio. There is a designated pediatric respiratory therapist team that covers the pediatric inpatient unit, the 11-bed pediatric emergency department (ED), and the 30-bed NICU. There are 2 respiratory therapists covering these units at all times.

Providers in the pediatric unit adopted the use of the Hospital Asthma Severity Score (HASS), a severity score developed at the affiliated freestanding children's hospital in 2013.[22] On admission, the patient was scored by the respiratory therapists and nurses together, and the respiratory therapist administered any respiratory treatments. Respiratory therapists and nurses reassessed the patient and assigned a HASS score hourly while the patient was on continuous albuterol.

Children with critical asthma on continuous albuterol have been admitted to the pediatric unit since 2006. Before the start of this pathway, CAN was administered for ≤2 hours sequentially and for a total of ≤4 hours during hospitalization. Indications for the initiation and discontinuation of CAN were variable between providers, as were indications for transfer. Heliox was available before this intervention but had not been given to a patient with critical asthma in >5 years.

Intervention

A multidisciplinary group that consisted of pediatric hospitalists, nurses, respiratory therapists, and a pharmacist reviewed and modified the original pathway from Wong et al.[19] Changes included the identification of inclusion criteria, definition of transfer criteria, and reduction of the threshold for the administration of heliox. In the pathway, the use of continuous albuterol, intravenous steroids, intravenous magnesium, and heliox as an augmentative therapy was standardized. The HASS score was used to guide these interventions. Heliox was initiated if a patient had a HASS score of ≥10 at any time, provided that the patient did not have a contraindication to heliox (air leak, inability to keep a face mask on during continuous albuterol, or tracheostomy). Transfer was initiated for any patient with a HASS score of ≥10 who was not a candidate for heliox or any patient with a HASS score of ≥12 at any point in the pathway. Finally, in the pathway, the weaning of albuterol was also standardized (Supplemental Fig 3).

Paper copies of the new pathway were printed and made available for use in the pediatric unit. Respiratory therapists, who administered the respiratory treatments, used a paper form for each patient on continuous albuterol and recorded measures in a data table on the form (see measures below).

Respiratory therapists, nurses, and physicians received training on the new pathway 1 to 2 months before implementation. Pathway education consisted of a continuing medical education–accredited lecture for nurses and lectures at staff meetings for respiratory therapists and physicians. We also provided handouts and e-mail updates with case discussions.

Historical controls for the study were collected from medical record reviews of all patients who met the inclusion criteria from September 2014 to August 2016. We launched the pathway in September 2016,

and data collection continued through December 2017. There was no change in the staffing of respiratory therapists or nurses during this time.

The community hospital's institutional review board waived review of this quality-improvement study.

Patients

Inclusion criteria for initiation of the pathway were as follows: age ≥2 years, a fraction of inspired oxygen requirement of <0.4, and the use of CAN while in the inpatient pediatric unit. Patients started on CAN in the ED, but those who discontinued CAN on arrival to the department were not included. Patients with pneumonia were not explicitly excluded, but their fraction of inspired oxygen had to be <0.4. In keeping with the preexisting admission policy, patients with a HASS score of ≥12 in the ED were not candidates for admission to the pediatric inpatient unit and therefore were not placed on the pathway.

Measures

Patient age and sex were recorded. Time of arrival to the unit and time of initiation of CAN were also recorded. Our primary outcomes were time to albuterol administered q4h and hospital LOS. The time to q4h albuterol administration was termed "time to clinical recovery" because this is the frequency of albuterol administration at which patients are discharged. Our secondary outcome was the transfer rate. Deviations from the pathway were recorded. The balancing measures were hospital readmission within 72 hours and the use of ICU-specific therapies in the unit while awaiting transfer. ICU-specific therapies were defined as terbutaline, high-flow nasal cannula, noninvasive positive-pressure ventilation, or endotracheal intubation with mechanical ventilation.

For patients in the baseline group, 3 pediatric hospitalists and 1 nurse extracted the measures from the electronic health record. For patients in the intervention group, the respiratory therapist providing patient care manually recoded the measures on the printed critical asthma pathway form. Additional measures for patients in the intervention group (eg, readmission) were extracted from the electronic health record by the same 3 pediatric hospitalists and nurse.

Data Analysis

We used descriptive statistics to report demographic and clinical characteristics and outcomes (LOS in hours, hours to q4h albuterol administration, and transfer rate). We used percentages for categorical variables and means (with SDs) for continuous variables. To explore differences between demographic and clinical factors and outcomes across the baseline and intervention periods, we used the 1-way analysis of variance test for differences in continuous variables and the χ^2 and Fisher's exact tests to assess differences in categorical variables. $P < .05$ was considered statistically significant for all analyses. Segmented regression analysis of interrupted time series was used to evaluate the impact of the clinical pathway intervention on LOS and hours to q4h albuterol administration. The bimonthly (once every 2 months) average LOS and time to clinical recovery were calculated throughout the baseline and intervention periods. Interrupted time series analyses were conducted by using segmented regression models to estimate the impact of the clinical pathway intervention on LOS and hours to q4h albuterol administration. Intervention effects on outcomes were estimated, for which we accounted for baseline trend, correlation across time, and seasonality. Autoregressive models with stepwise autoregression, the maximum likelihood method, and lags of 7 were used. All analyses were performed by using SAS version 9.4 (SAS Institute, Inc, Cary, NC).

RESULTS

The baseline period was September 2014 to August 2016. The intervention period was September 2016 to December 2017. There were 69 patients on CAN during the baseline period, and 60 patients were in the intervention group. There were no significant differences in the demographic features of the 2 groups, including age and sex. The mean age in the baseline group was 7.1 years (SD 4.5 years), and the mean age was 7.4 years (SD 4.4 years) in the intervention group ($P = .68$).

There was also no significant difference in the maximum HASS score during hospitalization, which is a measure of illness severity ($P = .774$). Time on continuous albuterol significantly increased in the intervention group ($P = .002$; Table 1).

TABLE 1 Patient Demographics and Clinical Characteristics

	Baseline, September 2014 to August 2016, $n = 69$	Intervention, September 2016 to December 2017, $n = 60$	P
Patient demographics and clinical characteristics, n (%)			
Girls	24 (34.8)	23 (38.3)	.676
Age, y	7.1 (4.5)	7.4 (4.4)	.680
Maximum HASS score	9.7 (1.5)	9.3 (1.6)	.153
HASS score on admission	8.5 (1.6)	8.4 (1.8)	.774
Continuous albuterol use, h[a]	2.4 (2.0)	4.4 (4.0)	.002
Outcomes and balancing measures, mean (SD)			
LOS, h[a]	40.4 (21.9)	31.9 (17.0)	.029
Time to q4h albuterol administration, h[a]	27.5 (11.3)	17.4 (7.8)	<.001
Transfer to Boston Children's Hospital[a]	19 (27.5)	7 (11.7)	.025
HASS score at transfer	9.8 (1.6)	10.3 (1.6)	.514
ICU therapy at South Shore Hospital	5 (7.3)	1 (1.7)	.215
72-h bounce back	2 (2.9)	0 (0.0)	.499

[a] Meets clinical significance at $P < .05$.

The pathway was adhered to for 36 patients (60% of the intervention group). Of the 24 patients who had deviations, 20 of them deviated by not starting heliox despite meeting criteria but otherwise adhered to the pathway.

Effect on Time to Clinical Recovery and LOS

There was a statistically significant decrease in LOS ($P = .029$) and time to clinical recovery (q4h albuterol administration; $P \leq .001$) between the baseline and intervention groups in the bivariate analysis (Table 1).

To take preexisting trends at baseline into account, we used a segmented regression analysis of interrupted time series to assess the magnitude of change between the baseline and intervention groups. There was no significant month-to-month trend in the mean LOS ($P = .417$) and hours to clinical recovery ($P = .577$) during the baseline period. Final segmented regression results indicate that at the beginning of the baseline period, the average LOS was 45 hours. On average, LOS was reduced by ~12.4 hours (SE 10.2 hours) during the intervention period, but this difference was not statistically significant ($P = .239$; Fig 1).

The mean time to clinical recovery was significantly reduced by ~10.2 hours (SE 2.0 hours) between the baseline group (27.5 hours) and the intervention group (17.4 hours; Fig 2).

Effect on the Transfer Rate

There was a statistically significant decline in the transfer rate between the groups. Nineteen patients (27.5%) in the baseline group and 7 patients (11.7%) in the intervention group were transferred ($P = .025$; Table 1).

	Coefficient	SE	*t* Value	*P*-value
Mean LOS (hours)				
Intercept	44.99	6.45	6.98	—
Level change (baseline to postintervention)	−12.41	10.19	−1.22	.239

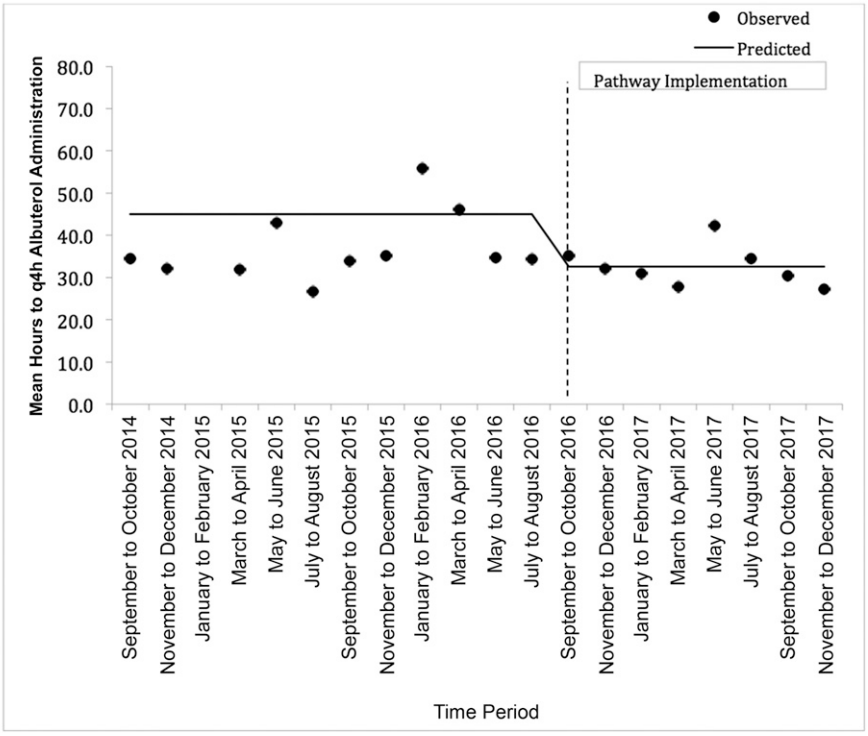

FIGURE 1 Interrupted time series analysis for LOS.

Balancing Measures

There was no increase in the percentage of patients who required ICU-specific interventions (terbutaline, high-flow nasal cannula, noninvasive positive-pressure ventilation, or endotracheal intubation with mechanical ventilation) in the pediatric unit before transfer (5 patients [7.3%] in the baseline group and 1 patient [1.7%] in the intervention group; $P = .215$). The 1 patient in the intervention group who required ICU-specific interventions was placed on high-flow nasal cannula before being transferred. There was no significant change in the number of patients who required readmission to the hospital within 72 hours of discharge (2 patients [2.9%] in the baseline group and 0 patients in the intervention group; $P = .499$; Table 1).

DISCUSSION

We set out to create a clinical pathway that could be used to guide the management and timely transfer of critically ill children with asthma in the community hospital setting. We have demonstrated that an asthma severity score–driven clinical pathway can reduce the time to clinical recovery for these patients. We were able to achieve a 37% relative reduction (absolute reduction of 10.4 hours) in the time it took to wean albuterol usage to q4h, which is a proxy of discharge readiness and clinical recovery. We also saw a 57% relative reduction in our transfer rate for these pediatric patients on continuous albuterol (27.5%–11.7%). We did not see a statistically significant effect on LOS with our interrupted time series analysis, which may reflect our small study population or inefficiencies in the discharge process.

In our study, we describe the implementation of a pathway for the management of children with asthma on continuous albuterol in the environment in which these patients most commonly present: the community hospital without a PICU.[21] Even in this unique setting, we saw a reduction in time to clinical recovery with the implementation of the clinical pathway for this critically ill group. In other words, patients got better faster when on this pathway. In addition, we saw a significant reduction in the transfer rate, with only

	Coefficient	SE	*t* Value	*P*-value
Mean time to q4h albuterol administration				
Intercept	27.51	1.28	21.43	—
Level change (baseline to postintervention)	–10.16	2.03	–5.01	<.0001

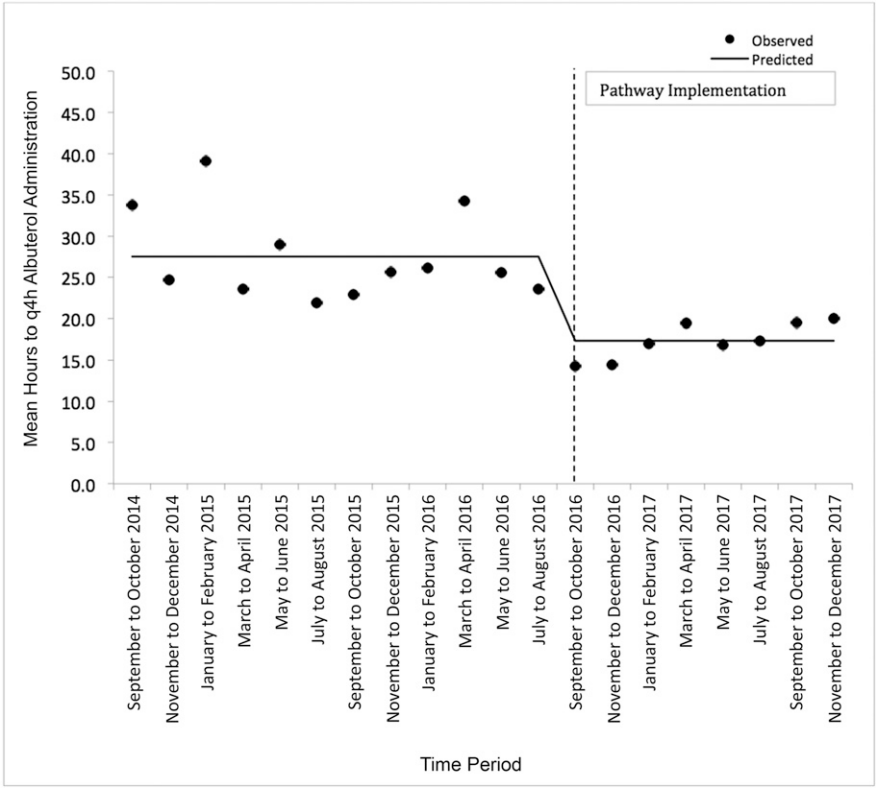

FIGURE 2 Interrupted time series analysis for time to clinical recovery (q4h albuterol).

11.7% of our intervention group requiring transfer. A reduction in the transfer rate is particularly meaningful in light of the costs to the medical system and to families that come with transfer.[23,24] In addition, patients who require transfer for ICU care may experience longer hospital and ICU stays.[25]

The use of clinical pathways for guiding decision-making for hospitalized children with asthma has been associated with improvements as diverse as decreased LOS, decreased hospital costs, increased use of controller medications after discharge, and increased use of asthma action plans.[4,6–8,10,26,27] These pathways have also been shown to be effective in community hospitals.[11] However, the use of pathways for pediatric patients who are critically ill with asthma and on continuous albuterol is not well described, particularly in the community hospital setting. This is despite recent evidence suggesting that the reduction of PICU LOS is the most effective way to limit costs in this population and that the vast majority of these patients never require noninvasive ventilation or invasive ventilation and may be safely cared for outside of the ICU setting.[28]

Interestingly, although the study in which Wong et al[19] describe a pathway implementation for critically ill patients with asthma in a freestanding children's hospital revealed a reduction in time on continuous albuterol, we saw an increase in time on continuous albuterol despite an overall reduction in time to clinical recovery. We believe that, outside of the ICU setting, this pathway was used to give people "permission" to use albuterol more aggressively, which ultimately improved patient outcomes. This is in keeping with studies that reveal that higher initial doses of albuterol may shorten ICU and hospital LOS.[14,15,26]

The community hospital setting poses unique challenges for the management of these patients. There needs to be careful consideration of when to transfer patients to ensure that ICU-specific therapies are not delayed. Given this consideration and the variability in the driving time between our community hospital and the affiliated children's hospital ICU (30–100 minutes via car depending on traffic), we defined conservative clinical transfer triggers. When thinking about the generalizability of this pathway's effect, the availability of physicians, respiratory therapists, and nurses who are comfortable managing these patients with challenging and time-consuming cases must be taken into consideration.

This study was limited by our relatively small patient population, which meant we were underpowered in detecting a significant LOS reduction. This study was conducted at a single center, and despite the use of a standardized tool, there may be site-specific practices or resources that prevent generalizability. We also had deviations from the pathway in 24 patients, 22 (83.3%) of whom deviated by not starting heliox when clinically indicated. Because heliox was offered simply as an adjunctive therapy, these 22 patients with deviations ultimately went through the same pathway as those without deviations, but this prevents us from commenting on the efficacy of heliox in decreasing the time to clinical recovery and LOS in this population (a topic that remains of considerable debate).[17,18] We did not assess whether transferred patients required ICU-specific therapies on arrival to the associated freestanding children's hospital. If many transferred patients do not require these therapies, we may be able to safely reduce our transfer rate in the future. We were underpowered in detecting a statistically significant decline in the readmission rate and in the percentage of patients who received ICU therapies in

the intervention group. However, these were both balancing measures that we were concerned would increase; in fact, both declined in our intervention group. Finally, we did not include a cost-benefit analysis, which may have helped us underline the importance of keeping these patients out of the ICU and our nonsignificant 12.4-hour reduction in LOS.

CONCLUSIONS

In this study, we describe the implementation of a clinical pathway for critically ill pediatric patients with asthma in a community hospital without a PICU. We were able to decrease the time to clinical recovery and transfer rate without an increase in key adverse events.

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