

Effects of a PICU Status Asthmaticus De-Escalation Pathway on Length of Stay and Albuterol Use

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Objectives: Evaluate the effects of an asthma de-escalation clinical pathway on selected outcomes for patients admitted to a PICU with status asthmaticus.

Design: Time series quality improvement trial.

Setting: PICU in a tertiary care children's hospital.

Patients: Children age 2–18 years old with a known diagnosis of asthma presenting with status asthmaticus.

Intervention: One-hundred five admissions to a PICU for status asthmaticus were treated according to a new de-escalation pathway between August 15, 2015, and August 30, 2016. This group was compared with a prepathway group of 141.

Measurements and Main Results: Primary outcome was variability in PICU length of stay. Secondary outcomes were median PICU length of stay, median hospital length of stay, and median duration a patient received continuous nebulized albuterol. The effectiveness of the intervention was tracked using control charts. The postpathway group demonstrated decreased variability of PICU length of stay and time receiving continuous albuterol. Statistically significant decreases were seen in median PICU length of stay (16 vs 13 hr; $p = 0.0009$), median duration a child spent receiving continuous nebulized albuterol (10.8 vs 7.3 hr; $p = 0.0008$), and median hospital length of stay (37 vs 31 hr; $p = 0.02$). Total

number of asthma assessments completed by respiratory therapists increased from 741 to 1,087.

Conclusions: Implementation of a PICU asthma de-escalation pathway demonstrated statistical decrease in the reported measures for children with status asthmaticus. Although the clinical significance of these changes may be debatable, the results demonstrate that efforts to standardize asthma care in the PICU setting is an area in need of further study. (*Pediatr Crit Care Med* 2018; XX:00–00)

Key Words: asthma; clinical pathways; critical care; length of stay; quality improvement; status asthmaticus

Over the past 15 years, rates of admission to PICUs for status asthmaticus have increased (1–3). In response, many pediatric hospitals have adopted a clinical asthma pathway for their inpatient services and/or emergency departments. Implementation of these pathways has been effective in reducing hospital length of stay (LOS), costs, and beta-agonist medication use without increasing readmission rates (4–7).

There is a paucity of information regarding attempts to standardize care of status asthmaticus patients in the PICU setting despite evidence that practice patterns vary widely within and among institutions (8). The reasons for this are not entirely clear although an interplay between a lack of high-quality evidence regarding treatments, the dynamic nature of critically ill asthma patients, and wide variability among providers' treatment preferences are all likely contributing factors.

Anecdotal experience from the staff in our PICU suggested that variation in the care of patients with status asthmaticus was contributing to a variable LOS. Institution of a clinical asthma pathway on the general medical floors in our hospital had successfully decreased LOS without increasing readmission rates. We hypothesized that a similar pathway may help decrease variability of care in our PICU. We initiated a quality improvement project with the primary aim of decreasing variability in care for patients with status asthmaticus. Secondary outcomes were median PICU LOS, median duration a patient received continuous nebulized albuterol, median length of

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Dr. Brennan was involved in the conception, design, and implementation of this project. He drafted the initial article, performed a portion of the statistical analysis, and created the control charts. Dr. Lowrie was involved in the conception, design, and implementation of this project. She reviewed the analysis and approved the final article for submission. Dr. Wooldridge was involved in the conception, design, and implementation of this project. She reviewed the analysis and approved the final article for submission.

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hospital stay, and readmission rate to the PICU of patients with status asthmaticus transferred to the medical floors during the same hospital stay.

MATERIALS AND METHODS

Setting

SSM Cardinal Glennon Children's Hospital is a tertiary care facility with a 21-bed PICU. The PICU is staffed 24 hours by board-certified pediatric intensivists, second- and third-year pediatric residents, respiratory therapists (RTs), and PICU nurse practitioners (NPs). PICU nurse staffing is no more than two patients to one nurse. The hospital has an established electronic medical record (EMR) for all charting in the PICU.

The EMR contains a flowsheet for charting respiratory therapy assessments based on our Clinical Asthma Score (CAS). The CAS is a combination of other pediatric clinical asthma scoring systems (7, 9) and is based on the modified Wood-Downes scoring system for pediatrics (10). In this flowsheet, the therapists ideally document each component of the CAS, the total CAS, the current frequency of albuterol, and any changes made to the albuterol frequency based on the new score.

Sample

Patients met inclusion criteria for the new pathway if they were between the ages of 2–18, had a previous diagnosis of asthma, and were admitted to the PICU between August 15, 2015, and August 30, 2016, with a primary diagnosis of status asthmaticus. Patients were ineligible for the new pathway if they had complicating diagnoses (i.e., bacterial pneumonia, acute chest syndrome), were receiving positive pressure ventilation, had mental status changes, or a CAS greater than 6 on their most recent assessment.

Intervention

This project was designed as a time series quality improvement trial and was separated into two “Plan, Do, Study, Act” (PDSA) cycles. The first cycle focused on the inter-rater agreement of the CAS when used in the PICU. This scoring system has been used by staff in other areas of the hospital for several years; however, the inter-rater reproducibility among practitioners in the PICU had never been specifically studied. Evaluation was performed via a scoring protocol where RTs, residents, PICU NP, and PICU attending physicians were given a maximum of 15 minutes each to assess the same patient and independently record their scores on a form.

In the second cycle, development of the new pathway (Appendix 1, Supplemental Digital Content 1, <http://links.lww.com/PCC/A642>) occurred through multidisciplinary meetings with representatives of the Divisions of Critical Care, Pulmonology, and the Respiratory Therapy Department. This group achieved consensus on variables for safely transitioning patients recovering from status asthmaticus to general floor care guided by the existing inpatient asthma pathway. The same transfer criteria was used for all patients. The new

PICU pathway was implemented on August 15, 2015, followed by revision of the PICU admission EMR order set to facilitate easier ordering of status asthmaticus treatments.

On the new pathway, patients were assessed hourly by the RTs in the PICU as per existing policy. Once the patient scored a CAS less than or equal to 6, a stepwise weaning of therapy was suggested which aligned well with the therapeutic approach of many of our PICU physicians and was based on previously published literature (11). The steps of the pathway were outlined on a flow sheet, which was electronically available to all team members. A hard copy was also placed in the PICU resource binder for reference.

Measures

According to the new pathway, patients with CAS less than or equal to 4 would no longer receive continuous nebulized albuterol. This represented the most significant departure from our current clinical practice. Adherence to the pathway was determined via review of each patient's respiratory therapy EMR flowsheet and expressed as a percentage of adherence. This was calculated by noting the number of assessments where a patient should (i.e., CAS 5–6) or should not (i.e., CAS $\leq$ 4) have received continuous albuterol and dividing by the total number of assessments in each of those two subcategories.

The admission CAS was defined as the first CAS assigned to the patient in the PICU by either a RT or physician within 30 minutes of arriving to the unit. The duration a patient received continuous nebulized albuterol was calculated using the electronic medical administration record (MAR). The time stamp generated when the albuterol was scanned into the system was taken as the starting point of the treatment. The endpoint was the time charted by the RT. When this time was not noted in the charting, the time the medication was discontinued in the MAR was taken as the endpoint of treatment. This duration of drug treatment includes the entire time the patient was in the PICU, regardless of their CAS. Sufficiently detailed data to make comparisons of albuterol duration only at CAS less than or equal to 6 were not available in the prepathway group; therefore, the total time of albuterol administration was used.

PICU LOS was calculated as the time difference between the PICU admission and transfer orders being placed. Hospital and PICU admission and discharge times were collected through reports generated by the Information Services Department. From these reports, PICU and overall hospital LOS were calculated. Transfer from the PICU was deemed appropriate once the patient could tolerate albuterol treatments spaced to every 2 hours, as is the existing hospital policy.

The balancing measure in this project was the number of PICU readmissions for refractory status asthmaticus after transfer to general floor care during the same hospitalization.

This Quality Improvement project was submitted to the St. Louis University Institutional Review Board and exempted from requiring approval due to the nature of the project.

TABLE 1. Median Scores With Interquartile Ranges Assigned by Each Assessor Grouped by Components of the Clinical Asthma Score

Clinical Asthma Score Categories		Median Score (IQR)			
Accessory muscle use	1 (0–1)	1 (1–1)	1 (0–1)	1 (1–1)	
Auscultation	1 (0–2)	0 (0–1.5)	1 (0–2)	1 (0.5–1.5)	
Dyspnea	0 (0–0)	0 (0–0)	0 (0–0)	0.5 (0–1)	
Inspiratory breath sounds	1 (1–1)	1 (0.5–1)	1 (1–1)	1 (1–1)	
Peripheral O ₂ saturation	1 (0–1)	2 (0.5–2)	1 (1–2)	1 (1–1.5)	
Total score	4 (2–4)	4 (3–5)	4.5 (3–6)	4 (2–5.5)	

IQR = interquartile range.

Analysis

Evaluation of inter-rater agreement for PDSA cycle 1 was performed using a Mann-Whitney *U* test with creation of median and interquartile and *p* value comparison tables (Tables 1 and 2). A *p* value of less than 0.05 was used to indicate a difference in score assignments. Control charts and statistical analysis were performed using JMP 10.0.2 (2012, SAS Institute, Cary, NC). To try and control for the effects of different sample sizes in each month, patients were arranged into subgroups of five for analysis of subgroup means when constructing the control charts. Control limits for each subgroup were defined using three sigma (-3σ) above and below the center line. These upper and lower limits are then divided into thirds designated zones A, B, and C. Special cause variation in the control charts was defined as a run of greater than or equal to seven consecutive points above or below the mean or two of three subsequent points in zone A or four of five subsequent points in Zone B or six or more consecutive points increasing or decreasing or any points outside of the control limits.

Kolmogorov-Smirnov testing of the data for PICU LOS, hospital LOS, and duration of continuous nebulized albuterol did not reveal normal distributions (all *p* > 0.05). Therefore, a Wilcoxon rank-sums test was used to compare median values in the pre- and postpathway groups for each outcome measure. Kolmogorov-Smirnov testing revealed the “Age” data followed a normal distribution. Therefore, a *t* test was performed to assess for statistical difference in the “Age” group. Pearson

chi-square analyses were performed on the CAS admission data (Table 3).

RESULTS

CAS Score Comparisons

Assessment of inter-rater agreement for CAS was done between November 2014 and April 2015. In total, 22 sets of 2 or more scores on 12 patients were obtained for a total of 50 scores. The median assigned scores correlated well between each group (Table 1). When comparing *p* values between groups of assessors, there was no statistically significant difference detected in their score assignments (Table 2).

Demographics

After introduction of the pathway, 105 patients were admitted to the PICU and treated using the suggested clinical guidelines. This group was compared with a historical cohort of 141 similar patients who had been admitted in the year prior. There was a difference in both age and gender with the postpathway group younger by 1.4 years with a more balanced male/female ratio (Table 3). Unfortunately, age and gender data were not available for 12 patients; 11 in the prepathway group and one in the postpathway group. The admission CAS of the two groups was not statistically different indicating that there was a similar severity of presenting disease. There was an increase in the overall number of assessments charted by RTs from 741

TABLE 2. Comparison of *p* Values for Components of the Clinical Asthma Score Between Groups of Assessors

Comparison Groups	Total Score	Peripheral O ₂ Saturation	Auscultation	Accessory Muscle Use	Breath Sounds	Dyspnea
Resident–NP	0.20	0.12	0.60	0.80	0.54	0.93
Resident–attending	0.19	0.41	0.86	0.21	0.65	0.10
Resident–RT	0.70	0.15	0.54	0.35	0.98	0.73
NP–attending	0.63	0.59	0.75	0.24	1.0	0.08
NP–RT	0.59	0.74	0.21	0.42	0.53	0.65
Attending–RT	0.43	0.47	0.38	0.62	0.62	0.21

NP = nurse practitioner, RT = respiratory therapist.

TABLE 3. Comparison of Postpathway and Prepathway Groups

Characteristics	Pre Pathway (n)	Post Pathway (n)	Total (n)	p
Admissions, n	141	105	246	
Male, n	88	56	144	
Female, n	42	48	90	
Mean age, yr	8.1	9.5		0.02
Admission Clinical Asthma Score				0.49
9	1	0	1	
8	2	4	6	
7	13	11	24	
6	27	16	43	
5	39	24	63	
4	27	27	54	
3	7	12	19	
2	6	5	11	
1	2	2	4	
Not charted	17	4	21	
Charted assessments by respiratory therapist	741	1,087	1,828	
Median number of assessments per patient	4	6		
Mean number of assessments per patient	5.4	8.0		

to 1,087, an increase in the median number of assessments per patient (4 vs 6) and an increase in the mean number of assessments per patient (5.4 vs 8.0).

LOS and Albuterol Duration

The introduction of a clinical asthma weaning pathway in our PICU was successful in reducing the median PICU LOS (**Fig. 1**) (16 vs 13 hr; $p = 0.0009$), median duration a child spent receiving continuous nebulized albuterol (**Fig. 2**) (10.8 vs 7.3 hr; $p = 0.0008$), and median hospital LOS (37 vs 31 hr; $p = 0.02$). All control charts display special cause variation as at least one point exceeded the upper control limits. The Xbar chart for PICU LOS displayed special cause variation between April 2016 and May 2016 where four of five points fell in Zone B. The Xbar chart for total hospital LOS (**Fig. 3**) displayed points outside the upper confidence limit but did not show a definite trend to a decrease in variability.

There were no PICU readmissions from the medical floors once a patient was transferred from the intensive care service in either group.

One patient in April 2016 and one patient in August 2016 were removed from analysis of the mean hospital LOS. These

patients required additional hospital services unrelated to their asthma diagnosis once their acute exacerbation had been treated.

Pathway Adherence

As mentioned previously, the most significant departure from the existing care model was the discontinuation of continuous nebulized albuterol therapy once the CAS reached 4, thus representing the most logical point to assess adherence. As detailed in the *Measures* section, adherence was assessed when the CAS was 5–6 and when it was less than or equal to 4. When the CAS was 5–6, adherence with continuous albuterol administration was 97.3%. When the CAS was less than or equal to 4, adherence with continuous albuterol discontinuation was 37.6%.

DISCUSSION

This pathway succeeded in its main objective of reducing the variability in PICU LOS as demonstrated by the period of decreased PICU LOS between April 2016 and May 2016 that met criteria for significance. The mean total time on continuous albuterol and the total LOS charts demonstrated a reduction in points outside the confidence limits in the “After” group. These are important trends as they suggest the measured outcomes moved from a state of large variability to one that is more stable.

A comparison of the median calculations shows statistically significant reductions in the time children stayed in the PICU, time they spent receiving continuous albuterol, and overall time they spent in the hospital. Documentation by RTs of patient status and response to therapy was also improved.

One positive outcome of this project was successful introduction of standardized treatment as possible to the PICU staff. As there are no formal guidelines for the intensive care management of this condition, practitioners often have their own approach, which may vary from that of their colleagues. Variability in practice patterns leads to variability in duration of PICU admission. Considering that ICUs often operate at or near capacity, having large swings in patient LOS can be problematic. Having a reasonable expectation of how long a given patient will remain in the ICU is important information to plan staffing and bed availability. In addition, a difference of 3 hours less PICU staff time per patient who is improving can free up nursing and physician time to focus on more acutely ill patients. Although adherence to the pathway was not as high as the authors would have hoped, this project demonstrated that introducing even small standardization measures may yield positive results without adversely affecting patient care.

The results of this study are consistent with those of previous interventions examining the impact of asthma care pathways on inpatient LOS (3–5). As there are no specific PICU-based studies available for comparison, it is difficult to judge whether these results would apply in all PICU settings. Anecdotally, the authors are aware of institutions which have PICU “step-down”

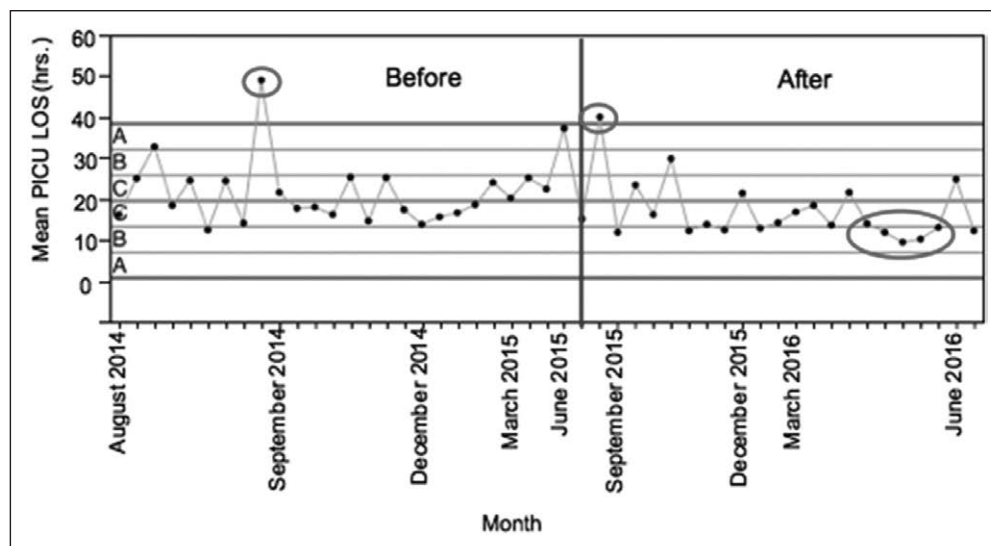


Figure 1. Xbar chart showing comparison of mean total PICU length of stay by subgroup "Before" and "After" initiation of weaning pathway. Circled points denote special cause variation.

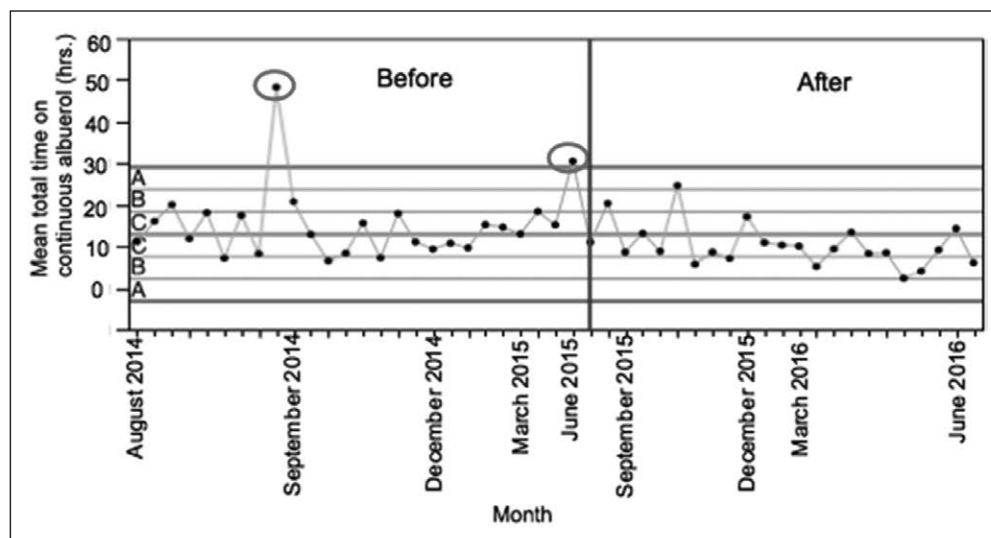


Figure 2. Xbar chart showing comparison of mean total time of continuous albuterol by subgroup "Before" and "After" initiation of weaning pathway. Circled points denote special cause variation.

units or even dedicated asthma units for certain subgroups of moderately ill patients. On these units, continuous nebulized albuterol may be given outside of the PICU, which would alter the results of a study using our defined outcome measures. Our asthma pathways (inpatient, emergency department, and PICU) are driven by respiratory therapy assessments and place a high workload on the therapists for this purpose. Institutions that do not have a large number of RTs may find this pathway challenging to duplicate.

There were no additional costs incurred by the institution in performing this study. The time RTs dedicated to patient care did not change as the current policy of the institution states that patients in the PICU with status asthmaticus are to receive hourly assessments. What was noted by these results is that RTs were more conscious of charting assessments every hour than they previously had been.

changes. Strength of the association is a slightly weaker category as the control charts show a trend toward less variability but no other consistent and sustained changes. However, in this specific context, the authors feel less variability of treatment is clinically significant because it has a direct impact on patient care and LOS. Specificity of association is weaker due to the confounding factors of low adherence to the pathway and the increased numbers of RT charted assessments. It is likely that increased numbers of charted assessments allowed for quicker decision-making by clinicians and produced the results observed. The consistency of association, biological gradient, and experimentation all require repeated iterations of a process while changing variables. Repeated PDSA cycles with the pathway in place were not performed during this project, and thus these areas cannot be assessed.

The main limitation of this study is the difficulty in wholly attributing the changes seen to the clinical pathway as it was designed. Although quality improvement initiatives are not intended to provide strong evidence for causality as a randomized controlled trial might, an attempt to produce a better assessment method has been adaptation of the epidemiologic Bradford-Hill criteria (12). This guideline can be used to examine nine factors in a quality improvement initiative and make a determination about how likely it is the given intervention produced the observed results. Those factors are strength of association, consistency of association, specificity of association, temporality, biological gradient (i.e., dose-response relationship), plausibility, coherence, analogy, and experimentation (i.e., manipulation of variables changes the outcome). When applied to this project, the strengths are in the areas of temporality, plausibility, coherence, and analogy. Our control charts show a change in outcomes with introduction of the pathway and based on existing literature, and it is plausible that a clinical pathway would result in these

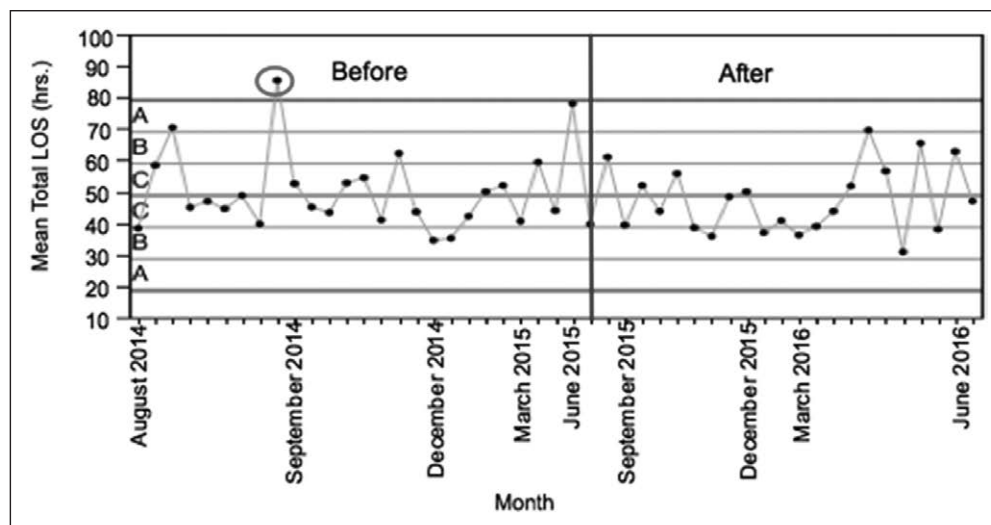


Figure 3. Xbar chart showing comparison of mean total length of hospital stay (LOS) by subgroup “Before” and “After” initiation of weaning pathway. Circled points denote special cause variation.

A second limitation is the inadequate power to assess for inter-rater agreement in the CAS during the first PDSA cycle. Although this was not the main purpose of the project, the new clinical pathway is built on the assumption that scores do not differ considerably between practitioners. A larger sample size would have provided greater confidence to providers that their score was similar to another practitioner’s score.

Last, the low adherence to weaning of albuterol once the CAS reached 4 is likely attributable to a variety of factors. The authors feel that even with this pathway, there were still variabilities in practitioner approaches to individual patients which could account for a portion of this result. In addition, there were also times where a staff member did not want to waste a recently dispensed drug or did not think it appropriate to attempt a wean while a child was asleep. Another PDSA cycle of this pathway would be required to find and address more specific causes for nonadherence.

In spite of the limitations, this project introduces a new perspective on the classically “stuck” child with asthma who cannot be weaned from their continuous albuterol. The results demonstrate that perhaps it is not entirely the pathophysiology of the disease that keeps patients in the ICU for prolonged periods of time. There is likely a significant contribution to LOS from variability in practitioner treatment approach and the availability of timely assessment data which affect clinical decision-making.

CONCLUSIONS

This quality improvement study analyzed the effects of a treatment de-escalation pathway for patients with status asthmaticus in a PICU. The intervention was successful in producing statistically significant reduction variability in the LOS, the median PICU LOS, median hospital LOS, and the median duration a patient received continuous albuterol. It was also successful in increasing the number and completeness of asthma assessments

by the RTs in the PICU. It was not successful in producing a sustained decrease in the PICU LOS, hospital LOS, or time a patient received continuous albuterol using accepted rules for special cause variability in control charts.

In our institution, the authors felt that these changes were significant enough to make a clinical impact; however, that conclusion cannot be applied to all PICUs depending on capacity, staffing, and patient turnover. Importantly, this study should serve as an initial example to examine further efforts to standardize asthma care in the PICU.

Future studies will determine if treatment pathways can be applied to the escalation of asthma treatment in a PICU. By standardizing the approach to PICU treatment, it may become easier to study the effectiveness of various medication doses and durations in the treatment of status asthmaticus, an area in need of significant research.

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