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Implementation of a Nurse-Driven Asthma Pathway in the Pediatric Intensive Care Unit

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Abstract

Background: Asthma is one of the most common conditions requiring admission to a pediatric intensive care unit. Dosing and weaning medications, particularly bronchodilators, are highly variable, and evidence-based weaning algorithms for clinicians are lacking in this setting. **Methods:** Patients admitted to a quaternary pediatric intensive care unit diagnosed with acute severe asthma were evaluated for time spent receiving continuous albuterol therapy, the length of stay in the intensive unit care unit, and the length of stay in the hospital. We developed an asthma pathway and continuous bronchodilator weaning algorithm to be used by bedside nurses. We then implemented two major Plan-Do-Study-Act cycles to facilitate the use of the pathway. They included implementing the algorithm and then integrating it as a clinical decision support tool in the electronic medical record. We used standard statistics and quality improvement methodology to analyze results. **Results:** One-hundred twenty-six patients met inclusion criteria during the study period, with 32 during baseline collection, 60 after weaning algorithm development and implementation, and 34 after clinical decision support implementation. Using quality improvement methodology, hours spent receiving continuous albuterol decreased from a mean of 43.6 to 28.6 hours after clinical decision support development. There were no differences in length of stay using standard statistics and QI methodology. **Conclusion:** Protocolized asthma management in the intensive care unit setting utilizing a multidisciplinary approach and clinical decision support tools for bedside nursing can reduce time spent receiving continuous albuterol and may lead to improved patient outcomes. *(Pediatr Qual Saf 2021;6:e503; doi: 10.1097/pq9.0000000000000503; Published online December 15, 2021.)*

INTRODUCTION

Asthma is the most common chronic disease of childhood in the United States, affecting 6.2 million children with over 135,000 hospital admissions per year and one of the most common reasons for admission to the pediatric intensive care unit (PICU).[1] Its economic burden has been estimated to be $56 billion annually.[2] Rates of admissions to PICUs have increased dramatically over the past decade for severe asthma exacerbations.[3] Despite the volume of children and adolescents treated in PICUs, there remain significant variations in the care delivered and outcomes achieved.[4]

Acute severe asthma, also known as critical asthma and/or status asthmaticus, represents a proportion of hospitalized asthmatics who are unresponsive to traditional asthma therapies on presentation, including repeated doses of beta-agonists. This distinct patient population typically requires continuous bronchodilator therapy and is at risk for acute respiratory failure from severe bronchospasm. Continuous nebulized albuterol therapy is safe and effective in acute severe asthma, though there remains little evidence on effective dosing and strategies of stepwise weaning.[5–7]

To achieve decreased variability and improve care, many pediatric hospitals have implemented standardized asthma pathways. These pathways have been developed in the emergency department, and inpatient settings, and have decreased LOS, costs, and exposure to medications.[8–12] Recently, quality improvement efforts in PICUs have shown promise to decrease the LOS and length of time spent receiving continuous nebulized bronchodilator

treatments.[13–15] These studies have used various objective asthma scores combined with standardized algorithms to de-escalate care.[13,14]

In our PICU, patients with acute severe asthma are cared for by a team of attending pediatric intensivists, pediatric critical care fellows, pediatric and emergency medicine residents, critical care nurses, and respiratory therapists (RTs). Nurses complete assessments at least hourly on all patients, providing bedside nurses the best perspective on patients' overall clinical trajectory. Many other areas of critical care management have been improved by implementing nurse-driven protocols, including reductions in catheter-associated urinary tract infections, optimized sedation management, and earlier initiation of complete enteral nutrition.[16–19] Further, incorporating these algorithms and protocols into the electronic medical record (EMR) as clinical decision support (CDS) tools has improved process measures.[20,21] We developed a quality improvement project to develop a standardized asthma pathway with a nurse-driven weaning algorithm for continuous nebulized albuterol therapy. Our overall goal was to reduce PICU LOS, total hospital LOS, and time on continuous albuterol therapy.

METHODS
Setting
MassGeneral for Children is a quaternary care pediatric hospital within Massachusetts General Hospital in Boston, Massachusetts, with a 14-bed medical/surgical PICU that admits over 1100 patients each year. The PICU is staffed by a multidisciplinary team as described above. The nursing to patient ratio is never more than 2:1.

MassGeneral for Children transitioned its EMR to a new system in April 2016.[22] The EMR contains pediatric-specific flowsheets, which allow the documentation of separate components of an objective asthma scoring tool known as the WARME. The WARME score was adapted from the Cincinnati Children's Hospital bronchiolitis score and represented a collection of validated components of other objective asthma scoring tools.[23] This score involves the assessment of wheezing, air exchange, respiratory rate, and expiratory time.

Eligible patients in the quality improvement pathway were between the ages of 12 months and 18 years, admitted to the PICU with a primary diagnosis of asthma, and required continuous albuterol therapy for more than 6 hours. We deliver continuous albuterol in our institution through the use of a high-flow nasal cannula system. We excluded patients if they required noninvasive positive pressure ventilation (separate from high-flow nasal cannula), intubation and mechanical ventilation, or escalation in therapy beyond continuous albuterol, including starting on terbutaline, theophylline, or ketamine infusions. We also excluded patients if they had a history of congenital or acquired cardiovascular disease, cystic fibrosis, or bronchopulmonary dysplasia. Patients on continuous albuterol for less than 6 hours were not included

to account for rapidly improved patients. These patients may not have initially required continuous treatments but were receiving albuterol on admission and then quickly transitioned off following assessment by the PICU team. Patients in our unit receiving continuous albuterol are also initiated on intravenous steroids and nebulized ipratropium bromide.

Intervention
We separated our quality improvement project into two major "Plan, Do, Study, Act" (PDSA) cycles between September 2016 and April 2019 and obtained baseline data from November 2016 through August 2017. A multidisciplinary group of pediatric critical care physicians, pediatric residents, pediatric critical care nurses, and RTs designed the quality improvement pathway based on available evidence, current institutional practices, and existing guidelines used in the emergency department and inpatient floors. In addition, we developed a key driver diagram to assist with designing interventions (Fig. 1).

The first part of our project involved standardizing workflow with selecting and implementing an objective asthma scoring tool to be used by physicians, nurses, and PICU RTs. We chose the WARME score based on its use elsewhere within our institution and its combination of elements of other commonly validated asthma scores, which RNs could quickly adopt in our unit. Nurses and RTs initially completed scoring on paper forms at the patient's bedside, and then subsequently, they were adapted into the EMR in November 2016. Scores were documented by nursing at least every 2 hours on all patients receiving continuous albuterol.

Following standard scoring assessment, we developed a weaning algorithm as our first PDSA cycle. The existing practice was to wean continuous albuterol in increments of 5 mg/h until down to 5 mg/h and requiring a physician assessment and specific order for each change followed by a transition to every 2-hour nebulized albuterol. The new protocol included inclusion/exclusion criteria described above and made additional recommendations for weaning (Fig. 2). The algorithm specified nursing assessments at least every 2 hours based on an existing policy with protocol orders based on the WARME score. The WARME scores range from 0 to 8, with a score < 4 indicating the ability of the nurse and RT to decrease continuous albuterol by 5 mg/h. Decreases are also indicated with two consecutive scores equal to 4. WARME score > 6 prompts contacting the responding clinician to consider an increase in therapy. Continuous albuterol infusion is weaned in increments of 5 mg/h until reaching 5 mg hourly. From 5 mg/h, the next wean is the discontinuation of the infusion and initiation of nebulized albuterol every 2 hours from infusion cessation as per existing policy. Initiation of the weaning protocol order during this PDSA was performed by entering a nurse communication order
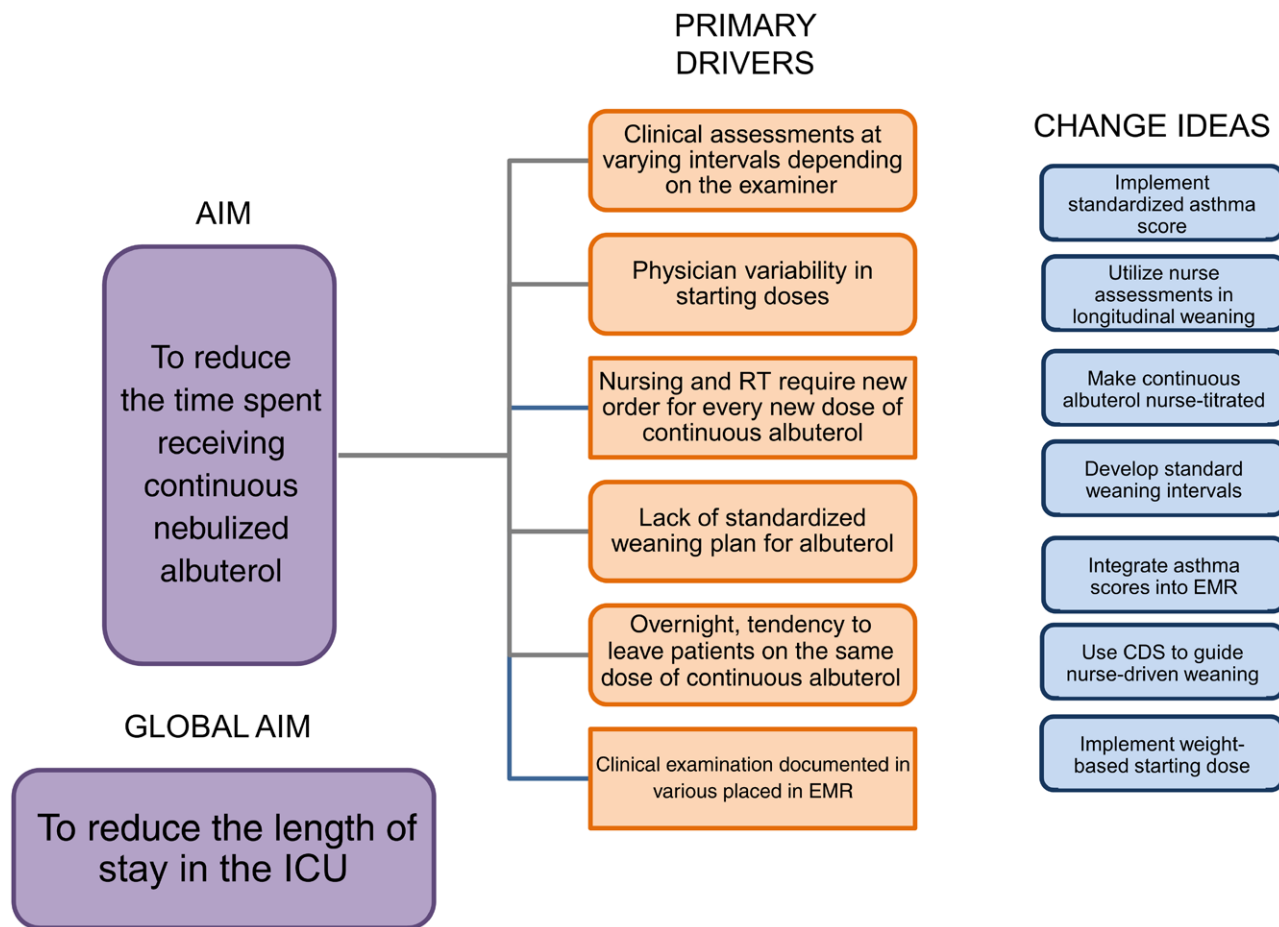
PRIMARY
DRIVERS

CHANGE IDEAS

AIM

To reduce
the time spent
receiving
continuous
nebulized
albuterol

Clinical assessments at
varying intervals depending
on the examiner

Physician variability in
starting doses

Nursing and RT require new
order for every new dose of
continuous albuterol

Lack of standardized
weaning plan for albuterol

Overnight, tendency to
leave patients on the same
dose of continuous albuterol

Clinical examination documented in
various placed in EMR

Implement
standardized asthma
score

Utilize nurse
assessments in
longitudinal weaning

Make continuous
albuterol nurse-titrated

Develop standard
weaning intervals

Integrate asthma
scores into EMR

Use CDS to guide
nurse-driven weaning

Implement weight-
based starting dose

GLOBAL AIM

To reduce the length of
stay in the ICU

Fig. 1. Specific aims and key driver diagram used to design interventions.

when the patient's physician felt the patient was ready to begin the weaning process.

The second PDSA cycle involved modifying the existing asthma orders in our EMR and integrating the new weaning algorithm into electronic documentation. This change included adding a titratable continuous albuterol infusion order that triggers a CDS tool that delivered an alert following every WARME score entered in the EMR flowsheet with instructions of what to do with the albuterol infusion based on the developed protocol.

Measures

The process measure for this improvement initiative was the duration of continuous albuterol therapy, measured in hours. We extracted time from the EMR through orders and flowsheet documentation review at set intervals throughout the study to test each change. Long-term outcomes of interest included length of stay (LOS) in the PICU, the total dose of continuous albuterol received, and total weight-based dosing of continuous albuterol. The balancing measure was total hospital LOS, as PICU interventions may change the dynamics of the patient transfer to the inpatient ward. We tracked our measures monthly through the improvement cycles.

Analysis

Statistical process control charts were used to monitor outcomes, with time-based data aggregated monthly into subgroups into an Xbar-S chart. Standard rules for identifying special cause variation were applied with two measures of special cause the focus; either eight consecutive points above or below the centerline or any point outside three-sigma control limits. In aggregate PDSA cycle periods, we calculated means and standard deviations for patient demographics and outcomes compared with ANOVA. P values < 0.05 (2-sided) were considered significant. Control charts were created and analyzed with QI Macros (2019 KnowWare International, Inc, Denver, Colo.). Statistical analyses were performed in SAS Software (Version 9.4, SAS Institute Inc., Cary, N.C.).

RESULTS

During the baseline data collection (November 2016–August 2017) and PDSA cycle time frame (November 2017–April 2019), 126 PICU patients met inclusion criteria, with 32 (25.4%) during baseline collection, 60 (47.6%) after weaning algorithm development and implementation (PDSA#1), and 34 (25.3%) after CDS
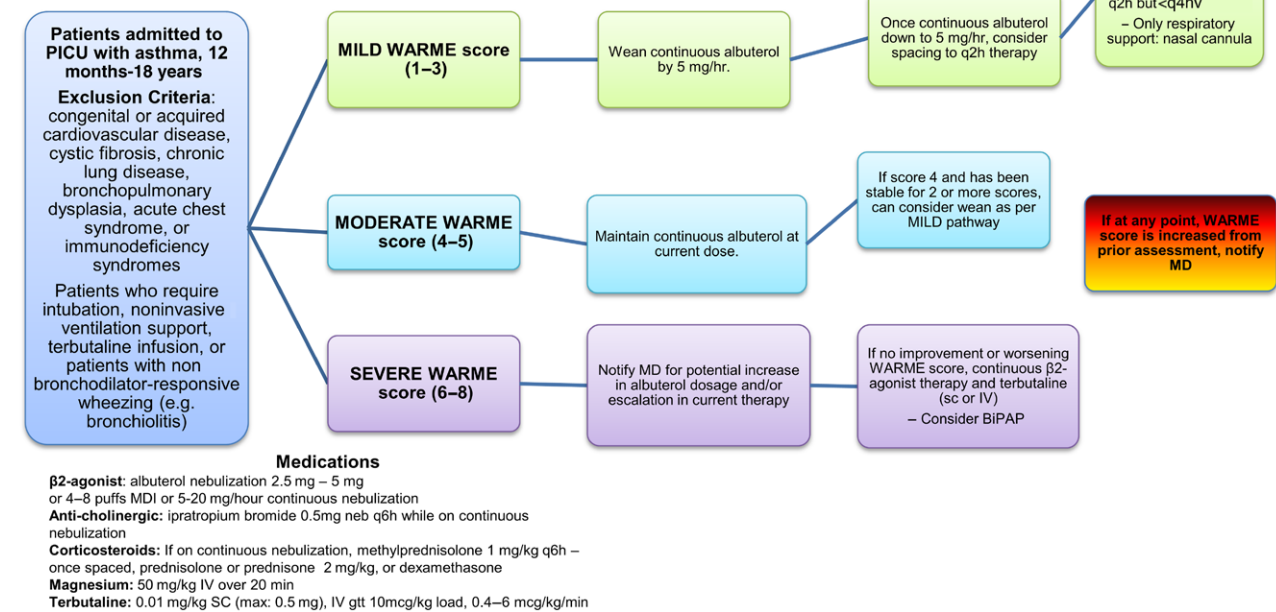
Fig. 2. Weaning algorithm developed for use in the PICU.

implementation (PDSA#2). The mean age and weight of all patients were 6.62 years (range 1–17 years) and 29.4 kg. The starting dose of continuous albuterol ranged from 10 mg/h to 20 mg/h with a mean dose by weight across the study period of 0.66 mg/kg/h (Table 1).

The statistical process chart for continuous albuterol duration is shown in Figure 3. PDSA cycles 1 and 2 are noted; Special cause variation was met in July 2018 just before implementing the CDS tool with a mean decrease of 45.9 to 29.2 hours and smaller control limits highlighting a less variable process.

Standard statistics revealed a mean ICU LOS of 2.96 days (±1.58) (Table 2), with no difference observed in ICU LOS across the PDSA cycles ($P = 0.32$). The SPC chart, shown in Figure 4 with PDSA cycles noted, shows

no evidence of special cause. Hospital LOS increased following the baseline period to a mean of 4.12 days (±1.76) during PDSA #1 but decreased after PDSA #2 to a mean of 3.85 days (± 1.44) ($P = 0.88$). Total albuterol dose varied from a mean of 439 to 463 mg without significant change. When weight-adjusted, total albuterol dose also did not differ across PDSA cycles ($P = 0.77$).

DISCUSSION

Severe acute asthma is a leading cause for PICU admission, and standardized pathways can help optimize quality measurement and possibly patient outcomes.[13,15,24] Our project implemented a nurse-driven pathway involving a standardized respiratory score, a weaning algorithm, and

Table 1. Patient Demographics

	PDSA #, mean (SD)				
	Baseline	**1**	**2**	**Total**	**P**
Age (years)	6.16 (3.36)	7.14 (3.96)	8.89 (16.6)	6.62 (3.85)	0.93
Weight (kg)	29.8 (18.6)	30.8 (19.8)	26.4 (15.5)	29.4 (18.3)	0.44
Starting albuterol dose (mg)	15 (5.96)	14.9 (5.86)	14.8 (5.43)	14.9 (5.72)	0.92
Starting albuterol dose (mg/kg)	0.71 (0.50)	0.60 (0.32)	0.72 (0.45)	0.66 (0.41)	0.89
Total	32	60	34	126	
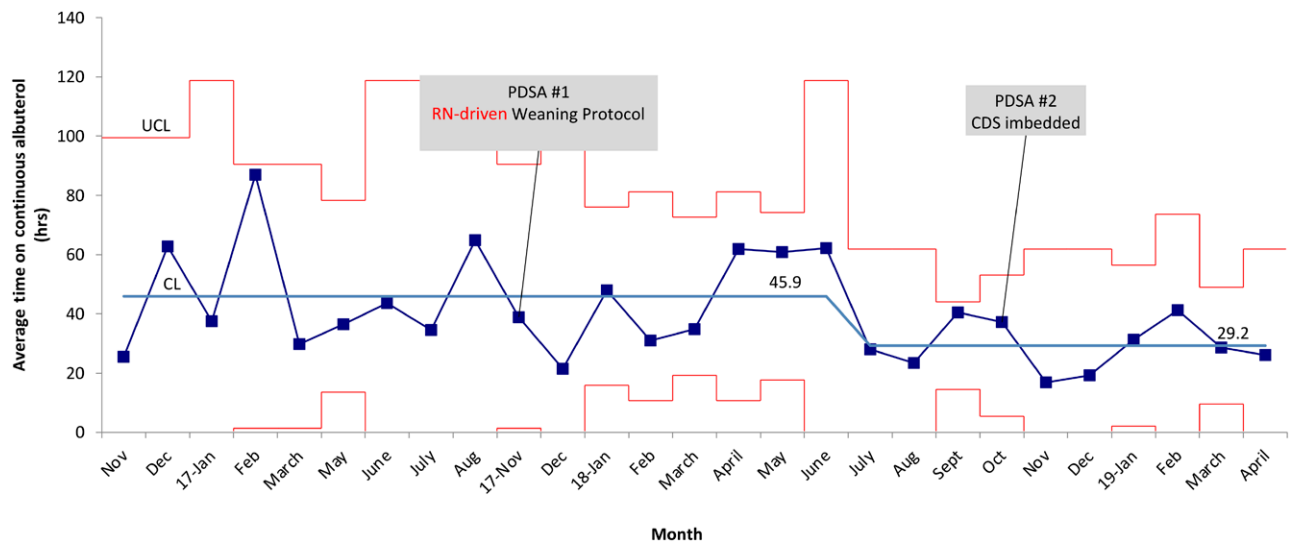
Fig. 3. XBar-S Chart demonstrating the duration of continuous albuterol (in hours) over the study period; control limits in red, data in blue.

Table 2. Outcomes of Quality Improvement Efforts

Outcome	PDSA #, mean (SD)			Total	P
	Baseline	1	2		
Time on continuous albuterol (h)	42.4 (30.6)	41.4 (30.0)	35.2 (27.6)	40.0 (34.0)	0.32
Total continuous albuterol received (mg)	439 (402)	493 (471)	463 (453)	471 (446)	0.83
Total continuous albuterol received (mg/kg)	20.1 (24.6)	19.0 (20.3)	18.7 (13.4)	19.2 (19.9)	0.77
ICU length of stay	3.44 (1.79)	2.68 (1.59)	3.0 (1.25)	2.96 (1.58)	0.28
Hospital length of stay	3.78 (1.84)	4.12 (1.76)	3.85 (1.44)	3.96 (1.70)	.88

a CDS tool that decreased time on continuous bronchodilators measured by QI methodology. This asthma weaning approach is unique in using bedside nurses as the leaders in pathway implementation, using a standardized protocol and titratable order embedded in the nursing-specific flowsheets of the EMR. Just as ICU nurses titrate vasoactive medications to specific goals with titratable orders, we applied the same principles to continuous albuterol therapy. Nurse-driven pathways have been successful with asthma management on pediatric floors in similar studies.[12] With consistent collaboration among the multidisciplinary team, including nurses, RTs, pharmacists, and physicians, protocolized asthma management can be performed with possible improvements in healthcare costs and resources in the ICU setting.

Brennan et al. were some of the first to show that implementing an asthma pathway in the PICU could improve outcomes.[13] Their study used a de-escalation pathway and a standardized asthma score to allow RTs to wean albuterol. As a result, they demonstrated reduced variability in PICU LOS and decreased time on continuous albuterol. Another study in the PICU also utilized RTs as the main providers utilizing a weaning algorithm. Still, the investigators could not show any significant LOS changes or time on continuous albuterol therapy. Our study was similar in using a standardized assessment score, but we also incorporated nursing as the primary decision-makers in scores and weaning. As the clinicians with the most bedside presence, the nurse's assessment is likely to be more frequent and potentially with improved reliability than periodic assessments by RTs and physicians.

Melendez et al similarly showed that a pathway with standardization of both escalation and weaning of asthma therapies led to decreased hospital LOS and time on continuous albuterol.[15] Their study utilized one weight-based dose for continuous albuterol and the routine use of Heliox for severe disease, which are not routine therapies or methods in our unit. Additionally, RTs and nurses led their pathway. Most recently, Miksa et al utilized a nurse and respiratory therapist-driven pathway leading to decreased PICU and hospital LOS and a decreased time to resolution of symptoms.[24] Unlike our study, they included patients on noninvasive positive pressure ventilation, including BiPAP and CPAP. Our study focused on safe de-escalation of care and thus excluded those who required advanced therapies or support other than high-flow nasal cannula through which we deliver albuterol.

An outcome in many PICU-based asthma studies is the decrease in time spent receiving continuous albuterol therapy.[13,24] Decreased time on continuous albuterol eliminates the need for a dedicated respiratory therapist and a requirement for ICU level of care in many hospitals,
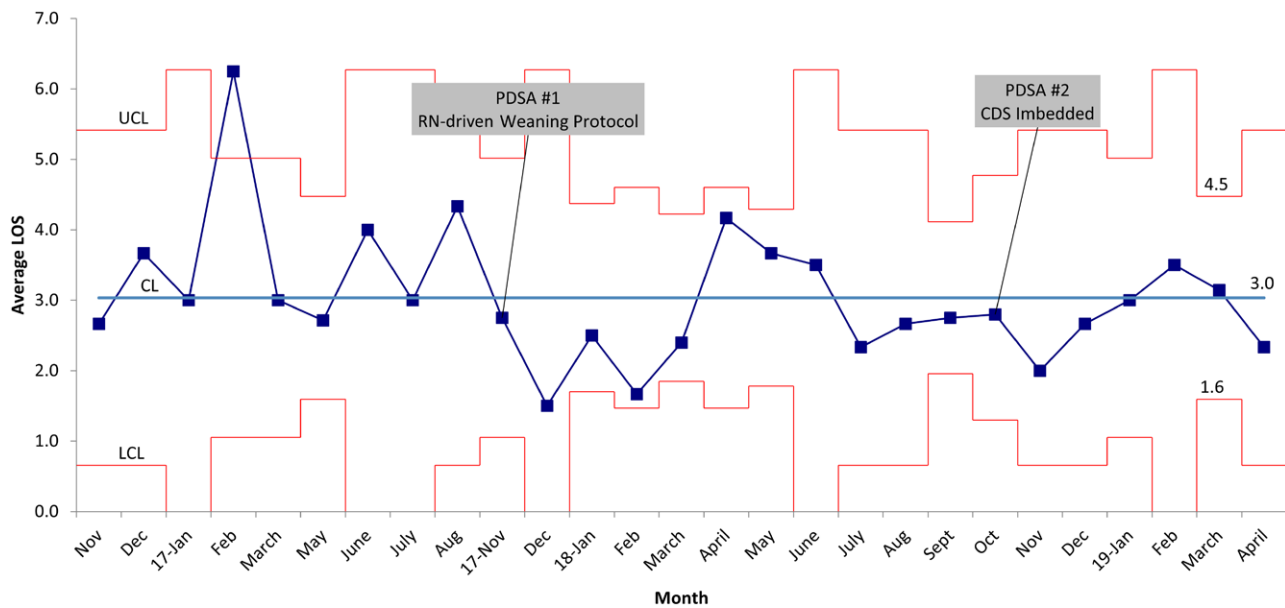
Fig. 4. XBar-S Chart demonstrating the LOS (in days) over the study period; control limits in red, data in blue.

thus freeing up resources and eventually moving toward earlier transfer. While our study did not show significant changes in the LOS, we measured this in days, potentially not capturing more minor changes. Other factors beyond clinical improvement may drive the timing of the transfer, including floor bed availability, PICU census, and time of day. We hypothesize that continued use and adherence to our pathway will further decrease time on continuous therapy and lead to decreased ICU LOS.

A unique aspect of our quality improvement approach not described in other asthma improvement reports is using a CDS within the EMR to promote pathway use for nursing and ordering providers. The use of CDS tools has had variable effects on healthcare outcomes in prior research.[20,21] For our quality improvement study, before implementing the CDS within the EMR, providers had to refer to the weaning algorithms in different places and use workarounds to order continuous albuterol as a titratable drug with range-objective goals. Integration of the algorithm within the EMR allows for immediate feedback upon entering a WARME score into a flowsheet by the bedside nurse; this allows for easier weaning of the drug immediately without seeking separate reference tools or contacting the ordering physician. Our results demonstrated that after the phased introduction of different pathway elements, the CDS implementation was associated with a continued decrease in time receiving continuous albuterol. While it is possible this occurred because it was part of our final PDSA cycle, it also allowed for widespread use of our algorithm. It also promoted nurse autonomy which likely contributed to its success. The use of CDS tools also allows our intervention to be sustainable and serves as a model for implementation in similar units.

Our study has several limitations. As we performed this study in a single institution using existing therapies and practices, it may not be generalizable to other larger units. We did not include variables to help describe the severity of illness over our different PDSA cycles. However, we captured data over several years and during similar seasons to capture the expected and real-world seasonal variability in asthma exacerbations in our region. We also were unable to capture deviations from the pathway, which likely occurred. These deviations are typically physician-specific changes in which a particular patient is deemed, in their opinion, not to meet criteria for weaning or is weaned outside the typical algorithm. These deviations could have led to patients remaining on continuous bronchodilators for longer. However, our results demonstrate that positive change can increase awareness and renewed education even with the introduction of a pathway.

CONCLUSIONS

Our study adds to the growing body of literature on the feasibility and success of protocolized asthma management in the ICU setting. With a collaborative approach to patient care and continued reassessment, improved outcomes are possible. The use of bedside nurses as primary providers in the titration of critical care medications has long proved beneficial.[17,19] Our study also shows this to be the case with respiratory medications. Future work is necessary to discern which parts of our protocol had the most success and determine the most effective pharmacotherapy in acute severe asthma.

DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

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