Improving Timeliness of β-Agonist and Corticosteroid Administration in Patients With Acute Wheezing

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Objective: Timely delivery of β-agonists and steroids to patients with acute recurrent wheezing is a key component of the National Heart, Lung, and Blood Institute recommended emergency department (ED) asthma care. We conducted an ED improvement initiative to standardize asthma care and improve time to treatments.

Methods: Our multidisciplinary team identified key contributing factors to timeliness, developed key driver diagrams, implemented and refined a management pathway, designed and executed rapid cycle improvements, and implemented interventions. A time series design was used to analyze outcomes with baseline data and continuous monitoring during active intervention steps. The primary outcomes analyzed were the times to first β-agonist and steroid administration. Secondary outcomes included admission rate, ED length of stay, and ED revisits.

Results: Assignment of the Pediatric Asthma Score, our initial pathway step, occurred in most patients within the first several months. Time to first β-agonist administration decreased from the baseline mean of 76 minutes to 27 minutes. Time to steroid administration decreased from the baseline mean of 108 minutes to 49 minutes. Mean monthly admission rate remained at 22% with no special cause variation identified. The ED revisit rate was not negatively impacted and, in most months, was 0%.

Conclusions: By standardizing asthma care in our ED and redesigning care delivery processes, care variation decreased and significant improvements in timeliness of β-agonist and steroid administration occurred.

Key Words: emergency department, asthma, β-agonist, steroids

Acute childhood asthma exacerbations account for over 26 million emergency department (ED) visits annually. Despite the frequency of these ED visits and established management guidelines, significant variation in care delivery processes and overuse of both diagnostic and therapeutic interventions have been reported. Corticosteroids and β-agonists are the mainstays of treatment for patients with moderate to severe acute asthma exacerbations. Multiple studies have demonstrated decreased hospitalization rates when corticosteroids are given early (<60 minutes from arrival) in the ED course. Studies have also shown that nurse-initiated ED protocols can reduce administration times for β-agonists and decrease admission rates. The National Heart, Lung, and Blood Institute (NHLBI) 2007 guidelines for the diagnosis and ED management of asthma recommend administration of β-agonists every 20 to 30 minutes and corticosteroids for moderate to severe exacerbations.

OUR PROBLEM

Pediatric patients with acute wheezing exacerbations visit EDs seeking reliable acute care. A significant degree of practice and care delivery process variation for asthma patients combined with a lack of consistent adherence to the NHLBI guidelines may contribute to significant delays in asthma medication delivery. To validate concerns about timeliness in our ED, baseline data for a 5-month period (January 2014 to May 2014) was obtained and significant time delays and wide variation in those times for medication administration were identified. An improvement team was chartered, an assessment was conducted, and several key factors believed to contribute to our medication delays were identified: ED structure, nurse and physician staffing models, absence of a management guideline, and lack of process clarity. The team theorized that, based on these factors, interventions focused on practice standardization and process redesign would result in the greatest improvement in timeliness of care. The team believed that implementation of an evidence-based pediatric ED asthma pathway was a critical step towards practice standardization in the ED.

SPECIFIC AIMS

Children ages 2 to 18 years with a history of asthma or recurrent wheezing who presented with wheeze, cough, upper respiratory tract infection symptoms, difficulty breathing, or hypoxia were assessed for wheezing and, when present, were assigned a Pediatric Asthma Score (PAS). The primary initiative aims were to administer the first β-agonist treatment to children with wheezing symptoms within 20 minutes of arrival and steroids within 60 minutes of arrival.

METHODS

Context

The University of North Carolina, Chapel Hill is a public academic medical center with over 650 adults and 150 pediatric inpatient beds, level IV pediatric and neonatal intensive care units, a level 1 trauma program, and emergency services. A major referral center for children with complex conditions, care is provided for more than 70,000 children from all 100 counties in North Carolina annually. The ED manages 55,000 adult and 15,000 pediatric patients annually and is comprised of multiple areas including the general ED area, the pediatric ED, a fast track area, and a behavioral health unit. There is no 24-hour...
observation unit. The pediatric ED is staffed by pediatric emergency medicine physicians 18 h/d. For the remaining 6 hours, general emergency medicine physicians provide pediatric care in the general ED. Nurses provide care to both adults and children in all areas; there is no pediatric-dedicated nursing or respiratory therapy staff. Implementation of a new scoring system, management pathway, and redesigned processes required the engagement and agreement of all of these clinicians to be successful. An effective ED improvement initiative to standardize the management of febrile children with central lines had been conducted in the preceding year, and we planned to use many of the strategies and lessons learned from that initiative.

**Improvement Process and Specific Interventions**

Our multidisciplinary ED improvement team was comprised of ED-attending physicians, residents, and nurses with ad hoc respiratory therapy, pharmacy, and information technology members. Two executive sponsors, the director of emergency services and the medical director of the pediatric ED, provided oversight and ongoing feedback throughout the initiative. We used standard quality improvement methods and tools to plan each step and implement changes. Active improvement work began in June 2014 and continued through January 2016. Ongoing monitoring continued into our maintenance phase, which started in February 2016, and continues at the time of this report.

During the first several months, our team focused on developing the ED asthma pathway and PAS and addressed the content, format, and feasibility of executing the proposed asthma pathway (Fig. 1). The pathway and score were refined during multiple Plan-Do-Study-Act (PDSA) cycles designed to test content and clarity before formal implementation. To implement and embed the final pathway into practice, we trained general and pediatric emergency physicians, residents, nurses, and respiratory therapists in scoring asthma acute severity and pathway content; provided peer coaching by nurse, resident, and attending physician champions; and reported biweekly performance data. Nurse accountability for assigning a PAS was clearly communicated and monitored by nursing leaders, including our nurse executive sponsor. Pathway-specific provider and nurse asthma order sets, with links to the pathway, were embedded into our electronic health record to provide decision support and streamline management.

With the asthma pathway implementation in progress, the team shifted focus to assessing and redesigning the processes required to effectively execute the pathway using key driver diagrams and process maps. The key driver diagram for initial β-agonist administration is displayed in Figure 2. Development of the overall patient management process involved input from frontline ED clinicians, residents, and attending physicians; multiple PDSA cycles to test proposed improvements; and a strategy that actively engaged staff and physicians in providing feedback and identifying barriers and solutions.

Key process improvements implemented included a process to expedite patient identification, a redesigned initial β-agonist administration process, incorporation of the PAS elements and self-calculating feature into the electronic health record, and routine stocking of the Pyxis (automated medication dispensing system) with steroids and appropriate β-agonist solutions. To achieve rapid patient identification, clinician responsibilities were expanded for greeters and residents. A successful model implemented during a prior ED improvement initiative was used and expanded to include our recurrent wheezing/asthma population. An asthma resident role with responsibility for surveillance and facilitation of early intervention for wheezing patients was created through a series of PDSA cycles. To streamline the β-agonist administration process, we eliminated role confusion between nurses and respiratory therapists, removed unnecessary steps, and created a decision tree for key tasks and responsibilities.

With the redesigned β-agonist administration process, the nurses received enhanced training in continuous β-agonist setup and delivery. This training was supplemented with instructional posters and peer coaching.

Strategies used to enhance adoption of the pathway and new processes focused on reporting data, results, and tips in a newsletter; conducting individual discussions with clinicians with performance gaps to identify challenges and potential solutions to test; providing rewards for best performance; and reporting aggregate performance data to institutional leaders.

Strategies currently used to ensure the sustainability of our improvements include onboarding training for new ED staff and monthly new resident training; nurse and resident champions to maintain awareness and enthusiasm; monthly performance data reports; and individual peer coaching. Our culture is shifting to one that embeds identification of barriers, recommendations for changes, and ongoing learning into daily practice.

**Study of the Interventions**

Measures selected and defined for this initiative included outcome, process, and balancing measures. Primary outcomes focused on the time from arrival to administration of the first β-agonist and steroids. Secondary outcomes included ED length of stay (LOS) and admission rate. Three key process indicators for use of the Asthma Pathway, monitored to assess adoption and adherence to the pathway, included the following: assignment of the PAS, ED administration of steroids for patients presenting with a PAS of greater than or equal to 3 and ED LOS. Emergency department revisits within 72 hours of an initial ED asthma visit resulting in discharge and ED LOS for all pediatric patients were monitored as primary balancing measures.

**Analysis**

Outcomes of the initiative were studied using a time series design with baseline data obtained from the prior 5 months and continuous monitoring during and after active intervention steps. The primary outcomes analyzed were the mean times from ED arrival to the administration of the first β-agonist treatment and steroids. Time to medication delivery was defined as the time from the patient's arrival to the ED to the time the medication administration was documented. Secondary outcomes included admission rate and ED LOS. The admission rate was defined as the percent of patients treated in the ED and admitted to any inpatient unit. Emergency department LOS was defined as the time from ED arrival to disposition; for admissions, this was from the time the patient arrived in the inpatient unit; for discharged patients, this was the time the patient was dismissed from the ED. The ED revisit rate was defined as the percent of patients treated and discharged from the ED with the diagnosis of acute asthma or wheezing exacerbation who returned to the ED for asthma/wheezing within 72 hours. A statistical process control chart was used to monitor improvement for all measures except the ED revisit rate, with control limits set at 3 SD and a shift of 7 or more points above or below the mean being indicative of special cause variation (equivalent to P < 0.01). Upper confidence limits and lower confidence limits are represented on the control chart as red dash lines. The center line on the control chart is the mean and is represented as a blue line. Qualitative data were collected during the multiple PDSA cycles and used to assess results.
Pediatric Asthma Exacerbation Protocol in the Emergency Department

The following information is intended as a guideline for the acute management of children with asthma. Management of your patient may require a more tailored approach.

Inclusion Criteria: 1-4 yrs or greater with history of asthma or recurrent wheezing presenting with acute onset of wheezing, cough, dyspnea, syncope, tachypnea, etc.

Exclusion Criteria: > 5 yrs of age; Diagnosis of viral bronchiolitis or group A streptococcus infection; Symptoms of Cystic Fibrosis, Chronic Lung Disease, Cardiac Disease, Airway Anomalies

1. Measure oxygen saturation and vital signs
2. Identify risk factors: Pneumonia/Influenza, ED admission, ED visits last year, Prior ED visits in last month, Presence of SABA per month, Poor perception of symptoms

1. Apply Continuous Cardiopulmonary Monitor and PULSE Oximetry. Administer O2 as needed to keep saturation >92%
2. Nurse to calculate Pediatric Asthma Score (PAS)
3. Notify Provider of PAS and begin appropriate order set based on PAS
4. Administer Corticosteroids **2mg/kg (PO/IV) PAS of 3 or greater unless previously administered in the last 12 hours.** *Seek medical direction for scores 0-2.*

**Preliminary PAS Score Calculation**

**Severe Distress = PAS 6-10**
- Administer nebulized 0.5mg/kg/hr max of 30 mg with terbutaline 0.5 mg to 1.0 mg every 10 minutes
- Perform & document PAS every 15 minutes
- Administer: (0.05mg/kg) nebulized 3.5mg with terbutaline 0.5mg nebs**
- Administer: (0.5mg/kg) nebulized 3.5mg with terbutaline 1.0mg nebs**
- May repeat up to 3 total scores in first hour**
- Consider adjunct therapy if PAS >10
- Repeat PAS 15 min after each treatment

**Mild Distress = PAS 1-2**
- Administer nebulized 0.5mg/kg/hr max of 30 mg with terbutaline 0.5mg to 1.0mg nebs
- Perform & document PAS every 15 minutes
- Administer: (0.05mg/kg) nebulized 3.5mg with terbutaline 0.5mg nebs**
- May repeat up to 3 total scores in first hour**
- Consider adjunct therapy if PAS >10
- Repeat PAS 15 min after each treatment

**PEDIATRIC ASTHMA SCORING**

1. PAS should be done prior to treatment and repeated 15 minutes after treatment (preferably by the same provider).
2. Add elements into a single score.

Element | Points
--- | ---
1. Respiratory Rate | 0 | 1 | 2
- 2-3 yrs
- 3-6 yrs
- 6 yrs+ | ≤ 30 | 30-35 | 35-40 |

2. Auscultation
- Ausculation anterior and posterior lung fields, assess abnormalities and presence of wheezing
- No Wheezes
- Expiratory Wheezes
- Inspiratory & expiratory wheezes or diminished breath sounds

3. Work of Breathing
- Assess for nasal flaring or retractions (suprasternal, intercostal, substernal)
- ≤ 1 sign
- 2 signs
- 3+ signs

4. Dyspnea
- Age developmentally appropriate
- If present and not showing physical signs of respiratory distress, score the present O2 level for this category
- Speaks full sentences, playful, AND takes PO well
- Speaks partial sentences, short breath OR poor PO
- Speaks short phrases, grunting, OR unable to take PO

5. O2 Requirements
- Do not take patients off supplemental oxygen to obtain score
- ≥ 92% on RA
- Supplemental oxygen required to maintain saturations above 92%

**Symptom**

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- Consider adjunct therapy if PAS >10
- Repeat PAS 15 min after each treatment

**Hourly Reassessment**

**Symptoms Resolve / Patient Stable - Discharge**
- Contact PCP for follow up
- Education regarding proper medication administration
- Reassess for at least 3 hours for cough or worsening symptoms
- Reassess supplementary oxygen for 2-3 days
- Consider maintenance therapy (inhaled corticosteroids)
- Provide patient with Asthma Action Plan

**FIGURE 1. Asthma pathway and PAS.**
Time to 1st Beta-Agonist

**SMART AIM**

- Reduce median time to 1st effective administration to patients 1-18 years of age presenting to the ED with acute asthma or wheezing exacerbation to 20 minutes.

**GLOBAL AIM**

- Improve the ED management of pediatric patients with asthma or wheezing exacerbation.

**KEY DRIVERS**

- Initial recognition that patient is wheezing or has wheezing-related symptoms
- Initial nursing assignment of PAS score
- Knowledge of PAS-effective asthma pathway and recommended treatment
- Availability of medication, equipment, and staff to administer beta-agonist
- Execute accurate order

**INTERVENTIONS**

- Develop process for early identification by greater and notification of novice
- Implement and refine the process for PAS assignment
- Implement and test Asthma Pathway
- Asthma Nursing and Provider order sets, PAS and Asthma Pathway added to EMR
- Access to delivery supplies for identified or non-identified
- Pyxis Machine stocked with necessary protocols
- Develop standard process for beta-agonist administration

**FIGURE 2.** First β-agonist key driver diagram.

and identify changes or new ideas to test. The University of North Carolina Institutional Review Board approved this project.

**RESULTS**

Over the course of this initiative, June 2014 through January 2016, 582 patient encounters for acute wheezing met criteria for assignment of an asthma score and the pediatric ED asthma pathway.

**Pathway Adoption**

Assignment and documentation of the PAS, a critical step in selecting the appropriate β-agonist and steroid treatment in the pathway, occurred in most patients soon after implementation (Fig. 3). Early in our peak respiratory season in January 2015, however, a significant decline was noted and investigated. A key contributing factor to the decline was a gap in nursing understanding that all patients with a history of asthma or recurrent wheezing presenting with upper respiratory tract symptoms were to have a PAS assessed. Individualized retraining and coaching by our nurse champions resolved this knowledge gap, and improvement has been sustained.

Improvement in steroid administration to patients with a PAS of greater than or equal to 3, a key indicator of Asthma Pathway use, was noted over the 17 months of active work (Fig. 4). Nonrandom variation was noted and investigated in July 2015. A new intern class and a low volume of asthma patients to facilitate learning were identified as key contributing factors to this occurrence, and adjustments to resident ED orientation were made. Monthly ED LOS improved over the course of the improvement initiative and remained lower than the pathway recommendation of 240 minutes (Fig. 5).

**Outcomes and Balancing Measures**

Mean administration times for the baseline 5 month period, January 2014 to May 2014, were 76 minutes (range, 11–312 minutes)

**FIGURE 3.** Percent of eligible patients with a PAS documented.
Steroid Administration

Definition: Number of patients with PAS of 3 at ED presentation receiving steroids in the ED/Number of patients with presenting PAS of 3. Excludes patients receiving steroids within 12 hours of ED arrival.

Data Source: Electronic Health Record

FIGURE 4. Rate of steroid administration for patients with PAS greater or equal to 3.

from ED arrival to first β-agonist administration and 108 minutes (range, 20–301 minutes) for steroids. With pathway implementation and refinement of our processes, the time from arrival to first β-agonist administration decreased to 27 minutes. Control charts demonstrate that first β-agonist administration was reliably less than 40 minutes within 8 months, an improvement that has been sustained, and is a more predictable process (Fig. 6). Of note, in March 2016, an increase in mean time to 54 minutes was noted and investigated. The increase in time was attributed to a 156-minute delay in administration in a patient with a mild exacerbation arriving during a high volume event during a late evening shift.

With clear pathway guidelines and availability of appropriate medications in the ED, the time from arrival to steroid administration decreased to 49 minutes (Fig. 7). Steroid administration was reliably under 60 minutes within 8 months with less process variation noted.

The mean monthly admission rate remained at 19% with no special cause variation identified after implementation of our changes (Fig. 8). The ED revisit rate, one measure to detect a potential unintended consequence of our process changes, was not negatively impacted and in most months has been 0%. Another balancing measure, LOS for all pediatric ED patients, did not increase as a result of this initiative. In addition, we monitored and reported ED census during the course of the initiative and did not note spikes in census resulting in special cause variation for timeliness metrics.

DISCUSSION

National Heart, Lung, and Blood Institute guidelines for ED management of pediatric asthma exacerbations emphasize timely medication administration. Recommendations include the administration of up to 3 doses of a short-acting β-agonist in the first

ED Length of Stay

Definition: Mean number of minutes from arrival to time asthma/wheezing patient is either discharged or transferred to an inpatient unit per month.

Data Source: Epic

FIGURE 5. Mean monthly LOS for all wheezing patients regardless of disposition.
hour of treatment for mild to moderate asthma exacerbations and high dose \(\beta\)-agonist and ipratropium,every 20 minutes or continuously for the first hour for severe asthma exacerbations.\(^6\) Evidence supports that use of ED clinical pathways to optimize asthma care results in expedited medication delivery and improved adherence to guidelines.\(^6\)\(^,\)\(^7\) Although multiple centers have implemented standardized pediatric asthma management protocols, outcomes have been mixed. Prospective studies have shown that these pathways reduced time to \(\beta\)-agonists and corticosteroid administration, improved guideline adherence, and decreased hospitalization rates.\(^8\)\(^-\)\(^12\)

As part of an improvement initiative to optimize acute asthma care across the continuum, our ED improvement initiative resulted in predictable management of acute wheezing episodes with streamlined processes, role clarity, timely medication delivery, and a reduced ED LOS. Through pathway development and process redesign, we addressed our 2 greatest areas for improvement: practice variation and medication delays. Pathway adoption occurred with training and individual coaching, asthma score inclusion in our electronic record nurse assessment screen, ongoing reporting of performance, and additional process modifications to optimize care delivery. Similar strategies were reported by Bekmezian et al\(^1\) in a prospective cohort study, which demonstrated improved adherence to National Institutes of Health guidelines and reduced hospital admissions for pediatric ED asthma patients using a clinical pathway. Through the use of mnemonics, educational sessions, email communication, posted asthma pathway signs, and linking the pathway to the EMR, they demonstrated improvements in quality and efficiency of asthma care. Miller et al\(^1\) showed improved adherence to a nurse-initiated
Improving Time to Medication in Acute Wheezing

Admission Rate

Definition: Number of asthma/wheezing patients admitted as inpatients/Number of asthma/wheezing patients seen per month.

Data Source: T System and Epic

![Graph showing admission rate over time with data points and trend lines.](image)

**FIGURE 8.** Rate of hospital admission monthly for wheezing patients.

The asthma protocol by posting signs in the triage area, sending monthly emails to nurses, discussing the protocol during the preshift huddle, and providing one-on-one triage nurse education. Other retrospective and prospective studies, however, demonstrated no improvement in outcomes after implementation of management pathways. Studies demonstrating no improvement in outcomes reported poor adherence to protocols postinitiation, with a significant amount of variability in asthma exacerbation treatment in the ED even after implementation. These findings suggest that ongoing efforts to ensure adherence and address barriers to asthma protocol use using quality tools is critical to achieve desired outcomes after implementation.

Changes implemented early in this initiative did not result in immediate reduction in β-agonist administration times although they likely, in aggregate, contributed to later successes. Using key Quality improvement tool, the cause and effect diagram, allowed us to effectively reassess our administration delays and a key contributing factor, delay in identification of the weezing patient, was identified. Understanding our system and what was modifiable was critical in the design of a new process for early patient recognition. Redesign of their triage process, a known contributor to delays in patient recognition and treatment, was not considered modifiable during the course of this initiative however, the pediatric emergency department hours were expanded to 24 hours/day, 7 days a week in January 2017. After several PDSA cycle, significant improvement in medication timeliness was achieved with the implementation of the asthma resident role and expansion of inpatient responsibilities for patient identification. New training and role descriptions were developed and incorporated into standard work.

Overall, our ED asthma improvement initiative significantly reduced practice and process variation and improved the timeliness of β-agonist and steroid administration. The success of our initiative can be attributed to several factors. We capitalized on prior experience with implementing a fewer and central line guideline and used strategies successful in that implementation. Quality improvement tool use, individual coaching and feedback, explicit expectations of all clinicians to participate in pathway revisions and process design, and process simplification to make it easier to do work played key roles in our improvements. Other important contributing factors were timely communication of results, recognition of individual exemplary performances, and deliberate celebrations of successes. Emergency department improvements have spread to our pediatric inpatient service with residents using their ED experience to incorporate the asthma score and pathway recommendations into inpatient practice. Several healthcare system partner institutions use the asthma order sets and have adopted many of the pathway recommendations. To sustain our improvements, we continue to monitor performance, investigate significant variation, and modify processes when appropriate.

A significant limitation of our initiative was the inability to modify our current triage process, a key driver for patient recognition, PAS assignment, and timely medication administration. We did not stratify results for timeliness based on the severity of the acute episode as, in developing our pathway, one guiding principle we incorporated was the intent to provide timely medication administration regardless of presenting severity. Although we did not perform a comprehensive assessment of the impact of our practice change on the care of other pediatric patients in our ED, we did monitor monthly overall ED LOS and the ED left without treatment rate and noted only random variation in these measures.

In conclusion, implementing best care practices and standardizing our processes has allowed us to provide the effective, efficient, and timely ED asthma care we sought to achieve. Steroids are consistently administered within 60 minutes of arrival and, although we have not yet attained consistent administration of the first β-agonist within 20 minutes, our overall time has significantly improved.

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