Improving Guideline-Based Care of Acute Asthma in a Pediatric Emergency Department

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abstract

BACKGROUND AND OBJECTIVE: Rapid repetitive administration of short-acting β-agonists (SABA) is the most effective means of reducing acute airflow obstruction in asthma. Little evidence exists that assesses process measures (ie, timeliness) and outcomes for asthma. We used quality improvement (QI) methods to improve emergency department care in accordance with national guidelines including timely SABA administration and use of asthma severity scores.

METHODS: The Model for Improvement was used and interventions were targeted at 4 key drivers: knowledge, engagement, decision support, and workflow enhancement. Time series analysis was performed and outcomes assessed on statistical process control charts.

RESULTS: Asthma severity scoring increased from 0% to >95% in triage and to >75% for repeat scores. Time to first SABA (T1) improved by 32.8 minutes (47%). T1 for low severity patients improved by 17.6 minutes (28%). T1 for high severity patients improved by 3.1 minutes to 18.1 minutes (15%). Time to third SABA (T3) improved by 30 minutes (24%). T3 for low severity patients improved by 42.5 minutes (29%) and T3 for high severity patients improved by 21 minutes (23%). Emergency department length of stay for low severity patients discharged to home improved by 29.3 minutes (15%). The number of asthma-related visits between 48-hour return hospitalizations increased from 114 to 261. The admission rate decreased 6.0%.

CONCLUSIONS: We implemented standardized asthma severity scoring with high rates of compliance, improved timely administration of β-agonist treatments, demonstrated early improvements in Emergency department length of stay, and reduced admission rates without increasing unplanned return admissions.

It is estimated that 9% of all children in the United States currently have a diagnosis of asthma.1 Asthma is 1 of the most common reasons children receive care in an emergency department (ED), accounting for nearly 2.1 million visits in the United States in 2009.2 According to the 2007 National Heart, Lung, and Blood Institute Expert Panel Recommendation guidelines (EPR-3),3 the primary goal of ED care for asthma exacerbations is the reversal of airflow obstruction, and rapid repetitive administration of short-acting β-agonists (SABAs) has been shown to be the most effective means of accomplishing this.4–7

The EPR-3 recommends that patients with moderate exacerbations receive...
up to 3 doses of SABA within their first hour of care and those with severe exacerbations should receive 1 dose of SABA every 20 minutes or the continuous administration of SABA for the first hour of care. A 2003 Cochrane Systematic Review of randomized control trials demonstrated decreased admission rates for patients receiving continuous versus intermittent administration of SABA, suggesting that more timely receipt of higher doses of SABA may improve outcomes.3

Despite these findings and the EPR-3 recommendations, we identified only 1 study directly assessing the relationship between timely administration of SABA and outcome measures such as ED length of stay (EDLOS) and admission rate.6 Sills et al6 found no significant relationship between timely SABA administration and EDLOS or admission rate; however, timeliness was based on the administration of at least 1 SABA within 60 minutes of ED arrival. Our aim is to improve the percentage of patients who receive up to 3 SABA treatments within 1 hour of triage, which may have more significant impact on outcomes.

In addition to timely and effective administration of SABA, effective ED management includes the assessment of initial severity of illness and the subsequent response to treatment. There is no single best measure of severity; however, sign and symptom scores are useful aids and can be predictive of hospitalization especially when repeat scores are obtained after treatment.9-14

Current-state assessment demonstrated appropriate use of corticosteroids and ipratropium; however, it revealed opportunity to improve both time to SABA therapy and adherence to standardized clinical assessments. Baseline time to first SABA (T1) was 71.8 minutes and baseline time to third SABA (T3) was 125.6 minutes. We theorized that (1) ED provider awareness of the safety and benefit of early and rapid administration of SABAs, (2) a standardized process of assessing illness severity, and (3) electronic medical record (EMR) tools to support a new care process would lead to a decrease in time to SABA administration, EDLOS, and admission rates for patients presenting with asthma.

Our primary aims for this project were to (1) record a Pediatric Asthma Severity Score10,11 (PASS) in triage for 90% of patients presenting with an asthma exacerbation; (2) to record at least 1 repeat PASS within 2 hours of triage for 75% of patients presenting with an asthma exacerbation; and (3) reduce time to first and third SABA by 25%. Our goal was to accomplish these aims within 12 months.

Our secondary aims were to (1) decrease EDLOS for both admitted and discharged asthma patients; and (2) decrease admission rate. Asthma-related return visits within 48 hours resulting in admission and EDLOS for all patients were tracked as balancing measures.

![Key driver diagram for implementation of PASS and improvement of timely SABA administration.](https://example.com/key-driver-diagram.png)

**FIGURE 1**

Key driver diagram for implementation of PASS and improvement of timely SABA administration.

| TABLE 1 Tools Implemented in EMR to Support Asthma Clinical Pathway |
|-----------------|------------------|-------------------|
| Tool             | Purpose                                      |
| PASS in EMR      | Improve scoring compliance. Available on all computers (bedside) and auto-calculates net score |
| Provider asthma order set | Facilitate order entry and standardize treatment |
| Asthma respiratory report | Facilitate rapid assessment of PASS and vital sign trends in relation to medication administration |
| Triage protocol  | Improve timely administration of first SABA. Standing protocol order allowing for nurse-initiated administration of initial SABA |
| Nurse order set  | Facilitate nurse order entry and improve compliance with triage protocol use |

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METHODS

Setting and Context

The Children’s Hospital of Wisconsin’s ED is a tertiary pediatric ED with 36 ED beds that sees over 60,000 visits annually. Asthma is the most common admitting diagnosis from the ED. Our ED is staffed by at least 1 pediatric emergency medicine (PEM) attending or fellow at all times. Fellows, advanced practice providers, and resident physicians assess patients and write orders for medications/interventions. ED nurses administer intermittent and continuous β-agonist therapy for nearly all asthma patients. Respiratory therapists aid in the care of only the most severely ill patients. This improvement work was supported by the section chief of PEM and ED nursing leadership.

Our improvement work coincided with implementation of a full EMR at our institution. Transition to a comprehensive EMR occurred in November 2012. Before full EMR implementation, computerized order entry was in use; however, no standing asthma order sets existed.

Interventions

The Model for Improvement was used as a framework for our improvement project. A project team of PEM physicians, nurses, and administrative leaders including the section chief of PEM and clinical nurse supervisor was established. Process mapping (Supplemental Figs 12, 13, and 14) and key driver diagrams (Fig 1) were used to gain better understanding of our system of care and to prioritize interventions.

Process maps demonstrated significant interprovider variation and highlighted areas for improvement. These included reducing wasted time in the process of order entry and medication administration. Appropriate variations in the timeliness of care on the basis of presenting severity were identified suggesting interventions needed to account for this difference and needed to be designed to address specific populations on the basis of severity of illness.

Our improvement efforts included all patients 2 to 18 years of age seen in the ED from May 2012 through November 2015 that received at least 1 SABA in the ED. Patients were excluded based on comorbidities including sickle cell disease, chronic lung disease, congenital heart disease, and concurrent pneumonia. Patients were identified based on International Classification of Diseases, Ninth Revision codes (493.xx) assigned to the visit.

Interventions were carried out in 2 phases. Phase 1 started July 2012...
and focused on standardized PASS assessments and provider education of best practices. Phase 2 commenced once standardized assessments were being done with high reliability and focused on the development and implementation of a clinical care pathway and enhancement of clinical workflow through integration of tools developed within the EMR. During phase 1 we implemented the PASS as our standardized asthma severity assessment tool. The PASS has good interrater reliability and is predictive of the need for ongoing care. PASS scores were integrated into the clinical pathway (Supplemental Fig 15) and care initiation triage protocol implemented in phase 2. The tool was initially introduced on paper and was quickly transitioned to electronic scoring with EMR implementation in November 2012. Implementation included lecture-based and just-in-time education of physicians and nurses on use of the tool. Simultaneously, best practice seminars were held for all providers emphasizing recommendations from the EPR-3 including use of standardized asthma severity assessments, timely and repetitive SABA administration, adjunctive use of ipratropium, and early corticosteroid administration.

Phase 2 focused on implementation of a clinical care pathway for all patients presenting with asthma. ED-based clinical pathways have been shown to reduce EDLOS and admission rates for asthma, as well as other acute illnesses. In keeping with EPR-3 recommendations, our pathway was stratified by presenting severity of illness (Mild = PASS 0–1, Moderate = PASS 2–3, Severe = PASS 4–6) to limit unnecessary exposure to medication while still providing optimal care. After development of our clinical care pathway, decision support tools were developed to translate the pathway into clinical practice (Table 1).

To further improve T3, a second best-practices seminar focused on provider care patterns was held in November 2014. Analysis of interval data demonstrated that >75% of patients with severe exacerbations (PASS ≥4) received a minimum of 3 SABA treatments; however, these treatments were rarely received within the first hour of care. As part of the best practices seminar, we recommended that continuous albuterol should be strongly considered as initial treatment of patients with severe exacerbations.

Finally, we implemented an audit and feedback process for provider-specific performance for T3 and nursing compliance.
with triage protocol use. Data were shared on a quarterly basis. Provider performance was shared in a deidentified manner allowing comparison with peer performance.

Study of the Interventions

Time series analysis was used to assess impact of individual interventions. Process and outcome measures were assessed monthly. Stratification was used to assess variation on the basis of differences in presenting asthma severity. Rational subgrouping was used to analyze variation between individual providers to direct an audit and feedback process. Statistical process control (SPC) charts for T3, subgrouped by individual provider, were generated (Supplemental Fig 16). Total SABA administrations before and after our interventions were measured to assess possible unintended outcomes.

Measures

Triage start time was identified as time zero for time-related metrics as we felt that triage start time reflects the beginning of the active phase of care, and significant change to the ED triage process was not in scope. We defined 3 SABA treatments as either 3 individual treatments (given every 20 minutes) or 1 hour of continuous SABA treatment (dose-equivalent to 3 individual treatments). If a patient received continuous SABA as their initial treatment, T3 was defined as administration time plus 40 minutes. Similarly, if a continuous SABA was given as the second treatment, T3 was defined as administration time plus 20 minutes. Analysis of baseline data demonstrated differences in outcomes on the basis of initial PASS score. Several stratification models were tested and a binary model with a threshold PASS of >3 demonstrated the greatest difference between groups and reduction of within-group variation. Therefore, in our measurement plan and reporting, results are stratified by initial PASS score of ≤3 and >3.

Analysis

SPC charts were used to assess change over time and rules for special cause variation were followed and used to adjust the mean. PASS compliance and admission rate were analyzed with p-charts. Time to treatment and EDLOS were analyzed with x-bar charts. Return visits resulting in admission were infrequent and therefore analyzed with a g-chart. SPC charts were generated by using QI-Charts (Version 2.0.22, Copyright 2009, Scoville Associates). Differences in median EDLOS and total albuterol administration pre- and postintervention were measured using the Mann-Whitney test. This analysis was conducted with SAS.

**Ethics**

The Children's Hospital of Wisconsin Institutional Review Board reviewed our project and deemed it quality improvement (QI) work not constituting human subjects research. To protect privacy, data were abstracted to and stored in a secure database.

**RESULTS**

From May 2012 through November 2015, there were 5552 patient encounters meeting inclusion criteria. The PASS score was successfully implemented and scores have been obtained in triage >95% of the time (Fig 2) for over 3 years. Repeat PASS scores have been documented within 2 hours 76% of the time for over 2 years (Fig 3).

Results are reported for the entire population and stratified by severity (low severity = PASS ≤3; high severity = PASS >3). T1 improved from 70.0 minutes to 37.2 minutes (32.8 minutes, 47% reduction; Fig 4). Some gain was temporarily lost between September 2014 and May 2015 during which time the mean T1 was 41.9 minutes; however, special cause variation was again noted starting June 2015 and T1 has been maintained at 37.2 minutes for 6 months.

We hypothesized that increased census and decreased nurse/provider to patient ratio negatively impacted T1 from September to May 2015. Monthly census was charted on a c-chart and special cause variation was noted from September 2014 through May 2015 (Supplemental Fig 17). Average monthly census during this period was increased by nearly 900 visits. Some of this variation is likely due to the enterovirus D68 outbreak identified across North America during the fall of 2014 as it was associated with increased severe respiratory illnesses among children.19,20

T1 for the lower severity patients improved from 62.7 minutes to 45.1 minutes (17.6 minutes, 28% reduction; Fig 5). Baseline T1 for high severity patients approached the goal time at 21.2 minutes and improved to 18.1 minutes (3.1 minutes, 15% reduction) and has been sustained for 11 months (Fig 6).

T3 for the entire population improved from 122.6 minutes to 92.6 minutes (30.0 minutes, 24% decrease) and has been sustained for 20 months (Fig 7). T3 for low severity patients improved from 148.5 minutes to 106.0 minutes (42.5 minutes, 29% reduction) and has been sustained for 20 months.

![X-bar Chart: T1 (PASS 0–3)](image-url)

FIGURE 5

X-bar chart demonstrating improved T1 for patients with initial PASS from 0 to 3.
T3 for high severity patients improved from 92.2 minutes to 71.0 minutes (21.2 minutes, 23% reduction; Fig 9) and has been sustained for 8 months.

Initial goals for PASS compliance as well as our initial goal of a 25% reduction in T1 were met. Additionally, we nearly met our 25% reduction goal for T3 in the entire population (24% reduction), and did see meaningful improvement in T3 for both low severity (29% reduction) and high severity patients (23% reduction). For patients with severe exacerbations, T1 currently meets guideline recommendations while T3 now more closely approaches guideline recommendations.

In addition to severity, EDLOS analysis was stratified by disposition (admission/discharge). EDLOS for admitted low severity patients remained stable at 323 minutes during the study period, whereas EDLOS for admitted high severity patients remained stable at 304 minutes. EDLOS for discharged low severity patients improved from 191.7 minutes to 162.4 minutes (29.3 minutes, 15% reduction) and this reduction has been sustained for 13 months (Fig 10). EDLOS for discharged high severity patients remained stable at 188 minutes.

To further assess the impact of timely treatment, we examined if receipt of 3 SABA within 60 minutes (guideline recommendations) affected EDLOS. Admitted patients who met guideline recommendations had a significantly shorter EDLOS; 289 minutes compared with 332 minutes ($P < .001$). EDLOS for discharged patients meeting this guideline recommendation was also shorter; 210 minutes compared with 225 minutes but was not significant ($P = .067$).

Differences in total SABA administration were measured before and after the recommendation to initiate care with continuous albuterol for patients with severe exacerbations. Before the update, discharged patients with severe exacerbations received an average of 2.9 treatments compared with 3.6 treatments after the update ($P < .001$), and admitted patients received an average of 5.7 treatments compared with 6.4 treatments after the update ($P < .001$). This was a net increase of <1 treatment per patient in both groups.

In December 2014 special cause variation was noted for admission rate (Fig 11), which dropped from 26.4% to 20.4% (6.0% absolute change, 23% relative change) and...
FIGURE 7
X-bar chart demonstrating improved T3 for all patients.

FIGURE 8
X-bar chart demonstrating improved T3 for patients with initial PASS from 0 to 3.
FIGURE 9
X-bar chart demonstrating improved T3 for patients with initial PASS from 4 to 6.

FIGURE 10
X-bar chart demonstrating decreased EDLOS for discharged patients with initial PASS 0 to 3.
has been sustained for 12 months. During this period, we also noted improvement and special cause variation in T1 and T3 for patients with severe exacerbations (Figs 6 and 9).

Between July 2012 and November 2015, there were 21 return visits within 48 hours resulting in admission; 0.39% of all patients presenting with asthma. Special cause was noted in January 2014 (Supplemental Fig 17). Before this, there was an average of 114 asthma-related patient visits between return admissions compared with 261 from January 24th through November 30th, 2015. Additionally, we saw no significant effect on EDLOS for the entire ED population during the intervention phases. Median EDLOS for admitted patients remained stable at 269 minutes, whereas median EDLOS for discharged patients remained stable at 125 minutes.

**DISCUSSION**

Through application of QI methodology and the integration of evidence into clinical workflow, we standardized asthma assessments with high rates of compliance and improved timely administration of SABA for patients seen with acute asthma exacerbations. Our findings suggest that timely and efficient care may lead to reductions in both EDLOS and admission rates. This is evidenced by the gains demonstrated in EDLOS for low severity patients discharged to home, and the fact that admitted patients who received their first 3 SABA within 60 minutes had significantly reduced EDLOS. Additionally, improvement in T3 for patients with severe exacerbations coincided with improvement in admission rates.

Although we did see a statistically significant increase in total SABA administration, it is unclear if this change was clinically significant or a negative effect. Improvement in T3 and increased albuterol administration coincided with decreased admission rates. Although the temporal relationship suggests that early aggressive treatment may positively affect admission rate, further study is needed to fully elucidate this relationship.

Several factors enabled our efforts. Implementation of a nurse triage protocol generated nurse buy-in and removed significant waste in early care. Although EMR implementation has been shown to have transient negative effects on patient flow in an ED setting, implementation facilitated development of higher reliability interventions. This is clearly seen by the dramatic improvement in PASS documentation compliance coinciding with EMR implementation. Lastly, stratifying
our results by presenting severity allowed us to identify distinct populations and target our interventions.

Although we demonstrated improvement of EDLOS for discharged patients with low severity exacerbations, we did not demonstrate other improvements in LOS. Timely receipt of therapy is likely not the primary determinant of EDLOS. For admitted patients especially, there are multiple downstream constraints outside the scope of this specific initiative. Additionally, the need to quickly identify patients requiring ongoing treatment in the hospital must be balanced with accurate identification of the correct population to avoid unnecessary hospitalizations and cost. Further gains are most likely to be had with continued efforts focused on patients with mild exacerbations. This will require the careful allocation of resources to ensure that we do not negatively impact the care of other sicker patients who arguably need the timeliest care.

During the intervention period, providers received feedback on multiple metrics related to asthma care increasing awareness that may have produced a Hawthorne effect in part responsible for the reduction in 48-hour return admissions. Increased awareness of performance may have changed behaviors regarding discharge decisions. Similar improvements have also been seen with implementation of ED clinical pathways for acute illnesses.12

Our study has several limitations. This study was conducted at a single institution, which may limit generalizability of our findings or the ability for other institutions to implement similar interventions. At the time of this initiative, we did not have the resources to conduct a cost analysis. Continued measurement is needed to ensure sustained improvement. Despite these limitations, our findings suggest that integration of evidence into clinical workflow can drive improvement.

CONCLUSIONS

We successfully improved timeliness of care for patients with acute asthma exacerbations without negatively affecting 48-hour return admissions or EDLOS for all patients. To our knowledge, this is the first study reporting results for the timely and repetitive administration of multiple SABAs within an hour and the effect on EDLOS and admission rates at a large academic pediatric ED.

ABBREVIATIONS
ED: emergency department
EDLOS: ED length of stay
EMR: electronic medical record
EPR-3: National Heart, Lung, and Blood Institute Expert Panel Recommendation guidelines
PASS: Pediatric Asthma Severity Score
PEM: pediatrics emergency medicine
QI: quality improvement
SABA: short-acting β-agonist
SPC: statistical process control
T1: time to first SABA
T3: time to third SABA

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