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Improving efficiency of pediatric emergency asthma treatment by using metered dose inhaler

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ABSTRACT

Objective: Evidence suggests using metered dose inhaler (MDI) to treat acute asthma in the Emergency Department reduces length of stay, though methods of implementation are lacking. We modified a treatment pathway to recommend use of MDI for mild-moderate asthma in a pediatric ED. **Methods:** A baseline review assessed discharged patients >2 years with an asthma diagnosis and non-emergent Emergency Severity Index triage assessment (3/4). Our multi-disciplinary team developed an intervention to increase MDI use instead of continuous albuterol (CA) using the following: (1) Redesign the asthma pathway and order set recommending MDI for ESI 3/4 patients. (2) Adding a conditional order for Respiratory Therapists to reassess and repeat MDI until patient reached mild assessment. The primary outcome was the percentage discharged within 3 hours, with a goal of a 10% increase compared to pre-intervention. Balancing measures included admission and revisit rates. **Results:** 7635 patients met eligibility before pathway change; 12,673 were seen in the subsequent 18 months. For target patients, the percentage discharged in <3 hours increased from 39% to 49%; reduction in median length of stay was 33 minutes. We identified special cause variation for reduction in CA use from 43% to 25%; Revisit rate and length of stay for higher-acuity patients did not change; overall asthma admissions decreased by 8%. Changes were sustained for 18 months. **Conclusion:** A change to an ED asthma pathway recommending MDI for mild-moderate asthma led to a rapid and sustained decrease in continuous albuterol use, length of stay, and admission rate.

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clinical pathway

Introduction

Asthma is the most common chronic illness of childhood and a leading cause of pediatric hospitalization and disability. [1] Care for asthma in the Emergency Department accounts for over 600,000 pediatric visits, over 70,000 hospitalizations [2] annually, and hospital-based management accounts for a large proportion of the 9 billion dollars [3] in annual healthcare costs for children [4,5]. In addition, asthma is a significant contributor to indirect costs due to missed days of work and school [6].

Improving the quality of asthma care has been a focus for national population health goals and evidence-based guidelines [7]. National guidelines for treatment of acute asthma recommend bronchodilators given either by nebulizer or by using metered dose inhaler with holding chamber along with corticosteroids and

supportive care [7]. Randomized trials and a systematic review comparing metered dose inhaler to nebulizer have found similar efficacy when albuterol is administered via either route [8] as well as reduced Emergency Department length of stay and fewer adverse effects for metered dose inhaler-treated patients, with some studies finding a reduction in hospitalization rates [9–11]. Use of metered dose inhalers also has the potential to improve value of care and reduce costs, since the equipment can be given to families to use after the Emergency Department visit.

Although experimental trials have suggested a clinical benefit to using metered dose inhaler instead of nebulization, there is little evidence regarding the impact of this modality in clinical practice. We sought to modify an existing Emergency Department clinical asthma treatment pathway to recommend metered dose inhaler treatment for children with mild-moderate

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asthma exacerbations and assess the impact on Emergency Department length of stay for discharged patients as compared to that of patients treated with continuous albuterol.

Our aim was to modify an asthma clinical pathway to increase by 10% the proportion of mild to moderate asthma patients discharged within 3 hours of Emergency Department arrival by three months after the implementation of the intervention.

Materials and methods

Context

This quality improvement project was performed at a 527-bed children's hospital with over 95,000 Emergency Department visits per year, of which over 8000 are for asthma. Sixty-percent of visits are patients who are mild to moderate in severity as defined by Emergency Severity Triage Index level 3–4 (see below). Prior quality improvement work had included implementation of an asthma clinical pathway with a web-based algorithm (<http://www.chop.edu/clinical-pathway/asthma-emergent-care-clinical-pathway>) and an associated order set in the electronic health record. Previous interventions focused on severe asthma while the goal of the current effort was to improve quality of care for mild-moderate asthma patients, who account for the majority of patients seen in the Emergency Department.

Interventions

We assembled a multidisciplinary project team including physicians, nurse practitioners, nurses, respiratory therapists, quality improvement, and data analytics staff. The team met 1–2 times per month during the project to plan and implement the intervention, assess progress and make modifications. To assess care at baseline we collected data from the electronic health record and conducted a detailed review of the medical records of 20 patients. We defined asthma using standard diagnosis codes and documentation of treatment with a bronchodilator, and mild-moderate severity based on a standardized Emergency Severity Index triage code of 3 or 4 out of a 5-point scale, with 1 being most severe. Asthma patients receive an Emergency Severity Index triage score upon arrival based on a standardized triage nursing assessment including respiratory exam that includes elements of the PASS respiratory score and pulse oximetry with criteria defined for levels 1–4 based on a standardized triage manual. Although we use a validated asthma

clinical score to document ongoing response to treatments [12], the Emergency Severity Index score was used to determine the initial pathway level (mild, moderate, or severe) to follow our current standard of care and to reduce the need for additional assessment and documentation before initiating care.

Prior to the intervention, the asthma clinical pathway allowed the option of treating mild-moderate patients with either albuterol given intermittently via metered dose inhaler or with a one-hour treatment of continuous albuterol and ipratropium, which was the recommended treatment for severe patients. The baseline data and record review determined that approximately 40% of Emergency Severity Index 3–4 patients received continuous albuterol, and 90% of these patients received a metered dose inhaler at discharge. Median Emergency Department length of stay was 3 hours. We conducted a detailed process review using a fishbone diagram and identified that a key driver of the choice to use CA was the concern that the provider (physician or nurse practitioners) would not be able to reassess the patient in a timely fashion to order additional metered dose inhaler treatments.

Our primary intervention was to modify the asthma pathway to recommend albuterol via metered dose inhaler for all mild-moderate patients. We modified the electronic health record order set to include a pre-set standard weight-based order for 4, 6, or 8 puffs based on weight categories of <10, 10–20, or >20 kg. All treatments were administered by respiratory therapists. To address provider concern about timeliness of reassessments, the order set included a total of three weight-based metered dose inhaler treatments to be given every 20 minutes; these could be discontinued by the respiratory therapist when the patient reached a mild asthma score assessment. All albuterol was administered with a valved holding chamber (AeroChamber plus Z STAT Monaghan Medical, Plattsburgh, New York), with all children less than 5 receiving the AeroChamber with a mask. Every asthma patient in the Emergency Department has their respiratory status assessed using a standardized clinical tool that incorporates work of breathing, breath sounds, and cough. Respiratory therapists utilize the PASS score, a score validated for assessment of pediatric asthma patients in the Emergency Department [12]. Additional standard treatments included prednisone or prednisolone given at 2mg/kg with a maximum of 60 mg. Approximately 6 months after the intervention, oral dexamethasone (0.6 mg/kg with a maximum of 8 mg) was added as an alternative corticosteroid as a separate initiative by the QI team based on a review of

Table 1. Patient characteristics before and after intervention.

	Pre-intervention <i>n</i> (%) (10/13-09/14)	Post-intervention <i>n</i> (%) (10/14-04/16)
Sex		
Male	4417 (57.5)	7204 (56.2)
Female	3218 (41.9)	5469 (42.7)
Ethnicity		
Hispanic	492 (6.4)	867 (6.8)
Non-Hispanic	7141 (93.0)	11,788 (92.0)
Race		
Black	5885 (76.6)	9580 (74.7)
White	1068 (13.9)	1802 (14.1)
Asian	127 (1.7)	244 (1.9)
Indian	25 (0.3)	69 (0.5)
Native Hawaiian or Other Pac Islander	11 (0.1)	11 (0.09)
Other	517 (6.7)	959 (7.5)
Age		
<5 years	2797 (36.4)	4678 (36.5)
≥5 years	4885 (63.6)	8142 (63.5)
Emergency Severity Index		
1	392 (5.1)	421 (3.3)
2	2752 (35.8)	4095 (31.9)
3	2674 (34.8)	4559 (35.6)
4	1655 (21.5)	3374 (26.3)
5	192 (2.5)	359 (2.8)
Disposition		
Admitted	3367(43.8)	4419(34.5)
	7682	12,820

evidence suggesting equivalence [13]. For appropriate patients, early administration of oral corticosteroids as consistent with the NAEPP guidelines remains the standard of care and this was not changed with the modifications in albuterol administration during our project.

Prior to implementation, the intervention was tested in a pilot fashion in a section of the Emergency Department known as the respiratory cohort, where asthma patients are frequently treated. The group reviewed changes to the order set and pathway web algorithm. Education of all stakeholders was performed through division conferences, electronic mail, and computer screensavers throughout the department.

Study of the intervention

To study our intervention we used a time series design using statistical process control charts to measure change in the processes of care and outcomes after the intervention. Baseline trends were identified for the year prior to the intervention to account for the seasonal nature of Emergency Department asthma visits and followed for the next 18 months to assess the impact and how the effect was sustained. The team-determined primary aim of the project was to increase the proportion of Emergency Severity Index 3 or 4 asthma patients discharged within 3 hours of Emergency Department arrival by 10%, within the first 3 months after implementing the intervention.

Cohort identification

We developed an analytic platform to query the electronic health record for all Emergency Department patients age 2 or older with an International Classification of Disease Diagnosis code for asthma (493.XX). To identify patients being acutely treated for asthma and account for changes in co-morbidity diagnosis coding practices for asthma that occurred 6 months after the intervention period, we limited analysis to patients who were treated with bronchodilators or corticosteroids in the Emergency Department. This project focused on patients with an initial Emergency Severity Index triage category of 3 or 4 who were discharged from the Emergency Department. For balancing measures such as admission rate we analyzed all Emergency Department asthma patients.

Measures

Process measures included the proportion of Emergency Severity Index 3 or 4 patients who received CA during their Emergency Department stay. Outcome measures included measures of Emergency Department length of stay for discharged patients including the proportion discharged within 3 hours and overall median length of stay measured from time of placement in an Emergency Department room to discharge. Balancing measures included overall Emergency Department admission

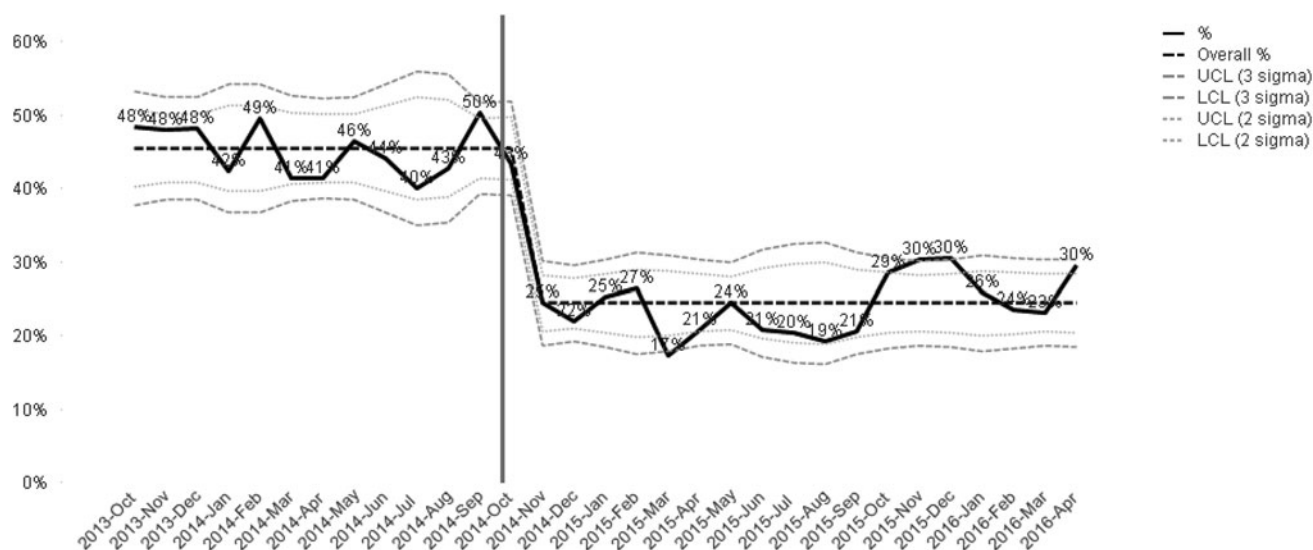


Figure 1. Control chart: Proportion of Emergency Severity Index 3-4 patients receiving continuous albuterol before and after pathway change.

rate, revisits to the Emergency Department within 72 hours and length of stay for Emergency Severity Index 1 or 2 patients. Assessment of LOS of higher ESI patients was intended to evaluate whether changing our approach to lower acuity patients affected more severe asthma patients. Revisits evaluate whether decreasing the intensity of acute treatment using MDI had an impact on subsequent return for care. Admission rates were used as a balancing measure to counter any concern that using MDI instead of CA might be less efficacious in this group thereby leading to more failed ED treatment courses and more admissions.

Analysis

Our measures were analyzed continuously using control charts with pulled data from our analytical platform. Special attention was paid to data points falling outside the upper control limit (+3 sigma) or lower control limit (−3 sigma). Additionally, we monitored for serial data points (greater than 8) above or below the mean.

Ethical considerations

The reporting of the aggregated outcomes of this quality improvement project were reviewed by the Office of Clinical Quality Improvement and the Institutional Review Board at the Children's Hospital of Philadelphia and classified as non-human subjects research.

Results

The changes were implemented on 27 October, 2014, and the team met regularly to review progress, and provide feedback. In January 2015 a modification to the order set was made to clarify that respiratory therapists could discontinue repeat assessments once the patient had reached a mild assessment. During the year prior to the intervention, 7635 patients met eligibility criteria for the pathway change. Demographic and clinical characteristics were similar to the 12,673 patients seen during the 18 months after the intervention (Table 1). Process measures related to the change in the pathway are displayed in Figure 1.

With regard to our primary outcome, the percent of Emergency Severity Index 3 or 4 patients discharged within 3 hours was approximately 39% for the year preceding our intervention. Within one month of pathway initiation, the percent of patients increased to 49%, meeting our goal of a 10% increase well before the expected 3 months. This change was sustained for the 18 months following the intervention (Figure 2).

Use of continuous albuterol for target patients decreased from 43 to 25% during the initial week after the pathway change. This change was also sustained in the 18 months following pathway intervention.

For other measures, the overall admission rate for all asthma patients seen in the Emergency Department in the year prior to our intervention was 42%. Beginning in November of 2014 (within a month of intervention), 34% of all patients were admitted and this change was sustained through the

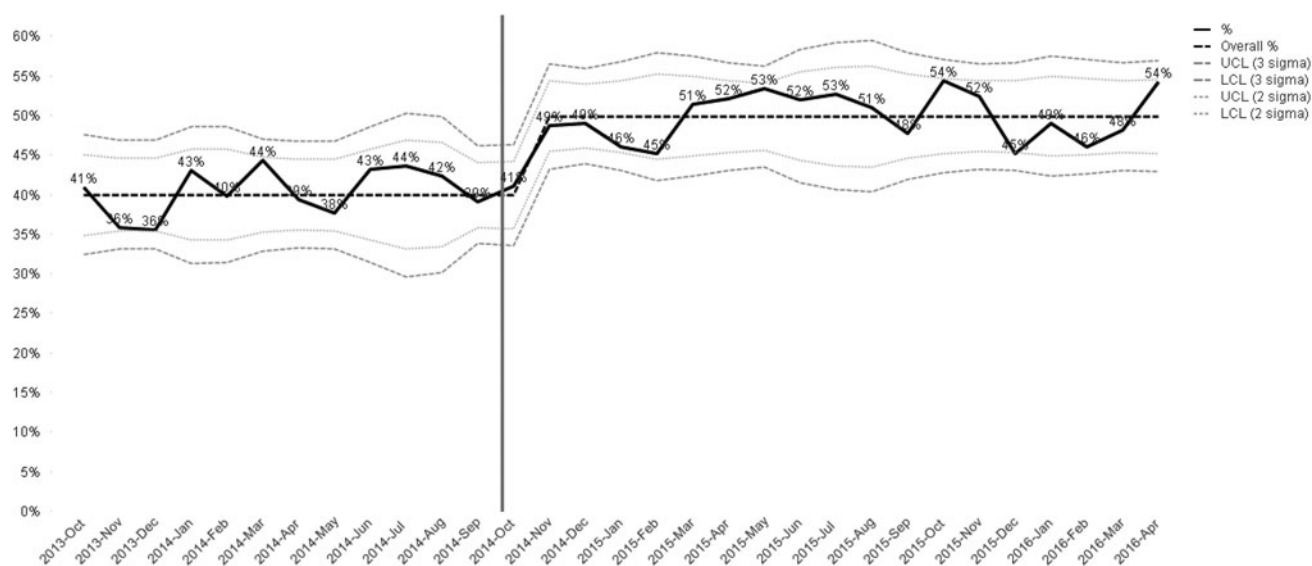


Figure 2. Control chart: Proportion of Emergency Severity Index 3-4 patients discharged within 3 hours before and after pathway change.

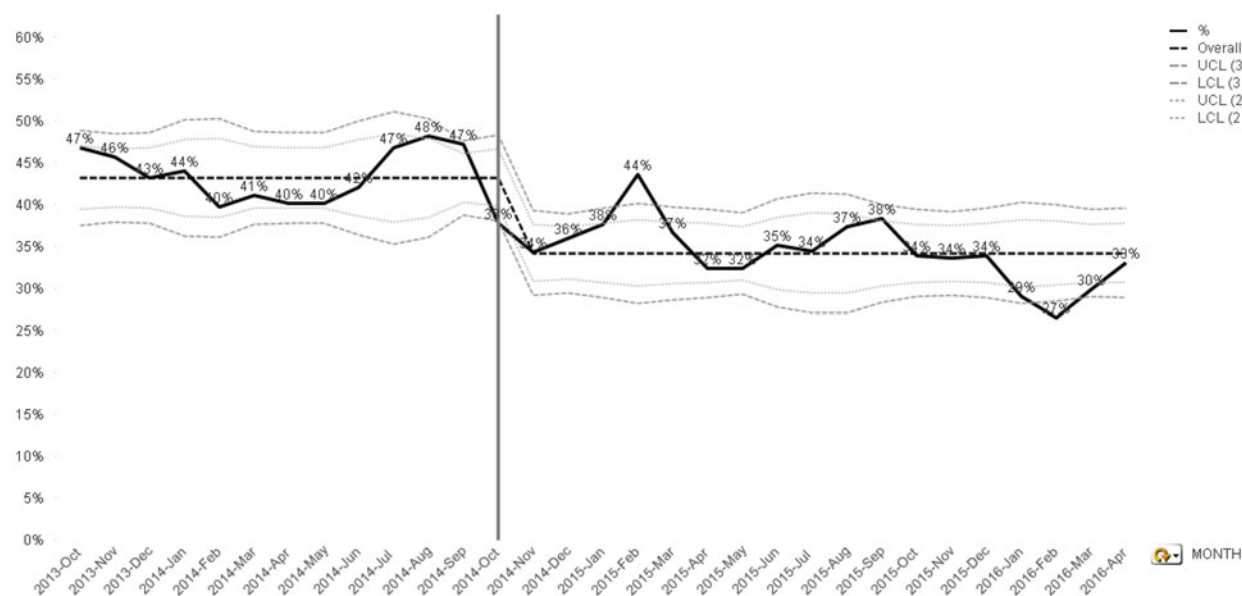


Figure 3. Overall ED admission rate for asthma before and after pathway change.

intervention period. We noted a single point out of control (above 3+ SD) in February of 2015, however by the subsequent month the data fell back in control and was sustained around the lower mean line through April of 2016 (Figure 3). Of note, the admission rate for Emergency Severity Index 3, 4, and 5 patients was 18.9% before the intervention and decreased to 15.2% after the intervention.

The revisit rate within 72 hours for patients with asthma during the intervention period was unchanged (0.97% prior to intervention and 1.02% following the intervention), showing no special cause variation. Length of stay for higher acuity patients was also not

changed, demonstrating the effectiveness of the intervention on the target group without affecting the efficiency of care for higher acuity patients.

Discussion

This intervention demonstrated a rapid and sustained change in use of metered dose inhaler instead of continuous albuterol for patients being treated with mild to moderate asthma exacerbations in a pediatric Emergency Department. The change in process was associated with a 10% increase in patients discharged within 3 hours of Emergency Department arrival and

a concurrent decrease by 8% in overall admission rate for all asthma patients. These changes occurred within days of pathway implementation and were sustained for greater than 18 months. Our results were consistent with those in prior prospective clinical trials and systematic reviews and add to this evidence base by demonstrating translation of these research results to a real-world clinical setting [10,11].

There are several reasons why use of metered dose inhaler for albuterol administration might result in more timely discharge from the Emergency Department. Prior to the pathway change, almost half of these patients with mild to moderate asthma exacerbations received an hour of nebulized continuous albuterol during the course of their Emergency Department stay. As part of the planning phase of this project, we queried Emergency Department providers about their reasons for prescribing aggressive bronchodilator treatment. These providers were concerned that they might not be able to return in a timely fashion to reassess the patient and wanted to make sure that enough treatment was given, with too much treatment being judged as better than too little. Our intervention was designed to address this concern by allowing respiratory therapists to reassess after giving each of 3 metered dose inhaler treatments and discontinue them if the patient had improved. This approach likely better matched treatment to patient needs. A recent study evaluated the introduction of a high-dose continuous albuterol protocol for moderate to severe patients in another pediatric Emergency Department and found an associated increase in length of stay, which the authors attributed to likely overtreatment of moderate patients [14]. Although efficacy for continuous albuterol has been observed compared to intermittent treatment in a meta-analysis of randomized trials, most of these studies were conducted in severe patients [15]. Our results demonstrate the importance of accurately calibrating the intensity of treatments with patient severity.

Other potential benefits of metered dose inhaler in increasing efficiency of Emergency Department asthma care include the ability to perform discharge teaching while administering Emergency Department treatment. In our baseline chart review, 90% of patients received metered dose inhaler teaching and equipment at discharge, resulting in many patients using both nebulizer and metered dose inhaler equipment. Combining metered dose inhaler teaching with treatment allows for improved use of resources in addition to reducing time of treatment associated with using both methods. Finally, use of metered dose

inhaler may result in reduced adverse events associated with bronchodilator treatment. In their systematic review of trials, Cates et al. measured a lower pulse rate and less tremor in children treated with metered dose inhaler compared to those treated with nebulizer [11]. Other potential effects of bronchodilators include transient hypoxemia due to ventilation-perfusion mismatch. Although we did not measure these adverse effects directly in this quality improvement project, it is possible that the presence of adverse effects may lead to longer observation time prior to discharge.

The reduction in overall admission rate for asthma associated with the pathway change was not a goal of the project, but is consistent with prior literature. A systematic review of trials in children under the age of five found a reduction in admission rate for metered dose inhaler treatment compared to nebulization [10]. A more recent Cochrane Collaboration review of trials across all age ranges found a strong trend towards reduced admissions that did not meet statistical significance [11]. Potential mechanisms for a reduction in admissions from use of metered dose inhaler include improved delivery of medication and reduced adverse effects, as discussed above. Another possible mechanism relates to cognitive bias in favor of more aggressive treatment. Providers may make decisions differently based on their initial perception of a patient's degree of illness, which is influenced by the interventions they received or the pathways on which they were placed. Prior research has found that Emergency Department providers perform fewer interventions for patients triaged to a "fast-track" area of an Emergency Department compared to other similarly ill patients [16]. It is possible that by treating asthma patients less aggressively with metered dose inhaler, providers may perceive them as less ill and able to be discharged. Further investigation to measure this association in other populations is warranted given the potentially substantial impact on reducing hospitalizations for this common childhood illness.

The success of this intervention was in part due to the culture of pathway-based care at our institution. Care providers in all areas of this academic setting are familiar with pathways and order sets leading to a high degree of compliance with institutional standards of care. In addition, the pathway group is comprised of a multi-disciplinary team who has successfully completed similar QI initiatives in the past. Finally, the changes initiated by the group were highly integrated into the electronic health record, facilitating rapid process changes. The use of the EHR can be a

contributor to consistent performance given that the tools and assessments used are consistent and reliable [17].

This intervention had several limitations. This was a single center quality initiative, which may not be generalizable to a larger population or multiple centers. However, asthma is typically managed according to NAEPP guidelines, and therefore relatively standardized, providing an opportunity for wider dissemination of proven effective practices. As with any observational study, other co-interventions may have influenced the processes and outcomes we measured. Overall, asthma care at our institution is highly standardized by the prior introduction of our clinical pathway and order sets, reducing the potential for other effects. The only other change in our asthma pathway was the introduction of dexamethasone as an optional corticosteroid for mild to moderate patients that occurred approximately 6 months after the pathway change recommending metered dose inhaler. Given that the process and outcome changes we observed occurred prior to this intervention, we do not believe this practice change significantly influenced our results. We did not assess other variables such as patient age or ability to use MDI and this could be the focus for future work. Finally, ESI is a proxy for severity but may not always approximate true patient severity. We have implemented a standardized triage manual that uses specific elements of the respiratory exam and other data to assign ESI classification, but it is possible that misclassification occurred.

Conclusions

In conclusion, we conducted a quality improvement project to recommend bronchodilator treatment with metered dose inhaler for patients with mild to moderate asthma exacerbations in a pediatric Emergency Department. The intervention was developed by a multi-disciplinary committee and employed a modification of an existing web-based pathway and electronic health record order set. Implementation of the changes resulted in a decrease in continuous albuterol use which was associated with an increase in the proportion of patients discharged within 3 hours and a reduction in overall admission rate for asthma. These changes were sustained for over 18 months after the implementation and have continued to be sustained beyond the period of the intervention. Future work should explore similar interventions in other populations and further assess impact on hospitalization and other outcomes.

Author Contributions

JJZ conceptualized and designed the initial project as a senior member of the QI team. RA, RJS, & EMD contributed to the organization and assessment of the quality improvement (QI) project. JJZ supervised the implementation of the initiative. AMR, BR, & DS participated in the initiation of the QI project. RA, KH & VM analyzed the data. RA drafted the manuscript, and all authors contributed substantially to its revision. RA takes responsibility for the paper as a whole.

Disclosure Statement

The authors have no conflicts of interest to disclose.

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