

Modification of an Established Pediatric Asthma Pathway Improves Evidence-Based, Efficient Care

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OBJECTIVE: In September 2011, an established pediatric asthma pathway at a tertiary care children's hospital underwent significant revision. Modifications included simplification of the visual layout, addition of evidence-based recommendations regarding medication use, and implementation of standardized admission criteria. The objective of this study was to determine the impact of the modified asthma pathway on pathway adherence, percentage of patients receiving evidence-based care, length of stay, and cost.

METHODS: Cases were identified by using *International Classification of Diseases, Ninth Revision, Clinical Modification* diagnosis codes. Data were analyzed for 24 months before and after pathway modification. Statistical process control was used to examine changes in processes of care, and interrupted time series was used to examine outcome measures, including length of stay and cost in the premodification and postmodification periods.

RESULTS: A total of 5584 patients were included (2928 premodification; 2656 postmodification). Pathway adherence was high (79%–88%) throughout the study period. The percentage of patients receiving evidence-based care improved after pathway modification, and the results were sustained for 2 years. There was also improved efficiency, with a 30-minute (10%) decrease in emergency department length of stay for patients admitted with asthma ($P = .006$). There was a nominal (<10%) increase in costs of asthma care for patients in the emergency department ($P = .04$) and no change for those admitted to the hospital.

CONCLUSIONS: Modification of an existing pediatric asthma pathway led to sustained improvement in provision of evidence-based care and patient flow without adversely affecting costs. Our results suggest that continuous re-evaluation of established clinical pathways can lead to changes in provider practices and improvements in patient care.

Asthma is the most common chronic illness in children. It accounts for >600 000 emergency department (ED) visits and 155 000 hospitalizations annually, making it a leading cause of pediatric hospitalizations in the United States.¹ Reported admission rates for children treated in EDs for asthma

exacerbations are as high as 53%.^{2–13} Evidence-based recommendations for acute asthma management developed by the National Heart, Lung and Blood Institute have been shown to improve acute asthma care.^{14–16} Unfortunately, there is often poor provider adherence to these recommendations,

abstract



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Dr Rutman conceptualized and designed the study (including the selection of outcome and balancing measures), was primarily responsible for the analyses and creation of the statistical process control charts, and drafted the initial manuscript; Drs Atkins, Migita, Foti, and Lion participated in study design and analysis, and critically reviewed the manuscript; Ms Spencer coordinated data extraction from preexisting databases and reviewed the manuscript; Dr Wright conceptualized and performed the cost analysis arm of the study and critically reviewed the manuscript; Dr Leu developed the electronic order sets, provided information technology support to the project, and reviewed the manuscript; Dr Zhou conducted interrupted time series analysis for the study and reviewed the manuscript; and Dr Mangione-Smith obtained funding for the project, provided oversight on all aspects of study design and analyses, and critically reviewed the manuscript. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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TABLE 1 Measures, Improvement Goals, and Asthma Pathway Modifications

Measure	Goal	Pathway Modification
Process		
Proportion of patients with asthma order set activated	Monitor provider adherence and order set use	Streamlined visual layout, multiphase electronic order set to mirror pathway progression
Proportion of eligible patients receiving intravenous magnesium sulfate in the ED	Increase magnesium sulfate use in children aged ≥ 6 y who are in severe respiratory distress (respiratory score, 9–12) after first hour of treatment from <10% to >50%	Addition of recommendations for intravenous magnesium sulfate added to second and third hour of ED pathway and order set
Proportion of patients admitted with asthma receiving ipratropium bromide on the inpatient unit	Decrease ipratropium bromide use in admitted patients from >70% to <5%	Removal of ipratropium bromide from inpatient phase of electronic order set
Proportion of admitted asthma patients receiving recommended steroid prescriptions ¹⁴ at hospital discharge	Increase prescription for prednisone or prednisolone at hospital discharge from 20% to >75%	Pathway and order set modified to reflect recommended steroid course prednisone or prednisolone (2 mg/kg for 5–10 d) for admitted patients
Outcome		
ED LOS	Decrease ED LOS for patients admitted	Addition of standardized admission criteria ²⁰
Hospital LOS	No change	NA
Balancing		
Proportion of patients with asthma admitted to the hospital	No change	NA
Unplanned returns to the ED and inpatient units	No change	NA
Cost	No change	NA

NA, not applicable.

TABLE 2 Demographic Characteristics of Asthma Population

Characteristic	Premodification (<i>n</i> = 2928)	Postmodification (<i>n</i> = 2656)
Sex		
Female	1108 (37.8)	946 (35.6)
Male	1820 (62.2)	1710 (64.4)
Age, y		
<2	591 (20.2)	478 (17.9)
2–4	1173 (40.1)	1055 (39.7)
5–12	1017 (34.7)	993 (37.4)
13–18	147 (5.0)	130 (4.9)
Race/ethnicity		
White	986 (33.7)	876 (32.9)
Hispanic	629 (21.5)	510 (19.2)
Other/mixed	568 (19.4)	533 (20.1)
Black	466 (15.9)	478 (17.9)
Asian	279 (9.5)	259 (9.8)
Language		
English	2257 (77.0)	2078 (78.2)
Spanish	424 (14.5)	319 (12.0)
Other	247 (8.4)	259 (9.8)
Insurance type		
Commercial	1430 (48.8)	1253 (47.2)
Public	1498 (51.2)	1403 (52.8)

Data are presented as *n* (%).

and the quality of asthma care suffers.^{17–19}

Asthma is the leading ED diagnosis resulting in hospital admission at our freestanding children's hospital. Because children with asthma comprise a significant proportion of the patients we see, improving asthma care brings us closer to the

goal of providing high-quality care for all patients. Our institution first implemented an ED and inpatient clinical pathway for asthma in 2002. As with any improvement initiative, re-evaluation is critical; repeated Plan-Do-Study-Act cycles resulted in modifications to our asthma pathway over time. In 2010, review of monthly quality metrics revealed

opportunities for improvement in the care of patients treated on both the ED and inpatient asthma pathways (Table 1).

Numerous quality improvement (QI) studies demonstrate that implementation of clinical pathways can improve outcomes for common pediatric conditions such as asthma,^{21–25} pneumonia,^{26–31} and sepsis.³² Often, the importance of institutional support and provider adherence to pathway recommendations are emphasized as key drivers of success. Because use of the asthma pathway was part of our institutional culture for >10 years, and baseline provider adherence to the pathway and electronic order set was high (~80%), we assumed modification of the preexisting pathway and order sets would be an effective means for improving targeted outcomes for patients with asthma.

The aim of the present project was to determine the impact of a modified asthma pathway and order sets on the percentage of patients receiving evidence-based care and on the efficiency of care provided.

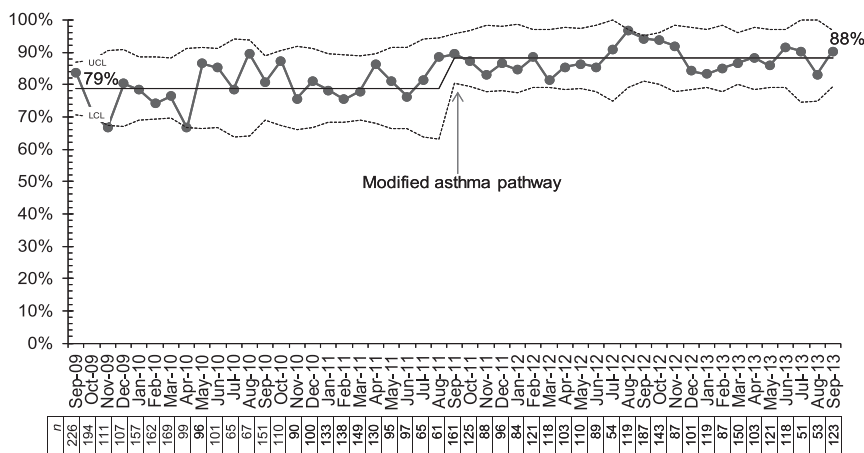


FIGURE 1
P-chart for proportion of patients with asthma order set activated in ED over time. LCL, lower control limit; UCL, upper control limit.

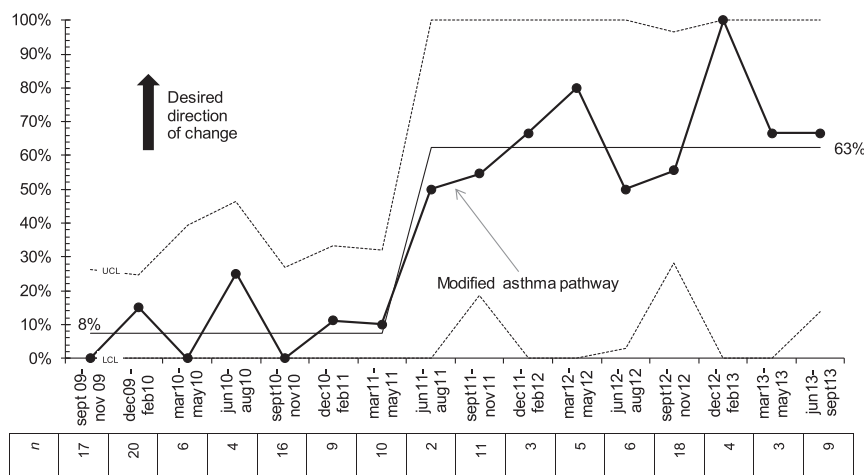


FIGURE 2
P-chart for proportion of patients with asthma receiving intravenous magnesium sulfate in the ED over time (subgrouped according to quarter). LCL, lower control limit; UCL, upper control limit.

METHODS

Context

The setting of the present study was a tertiary, university-affiliated, 323-bed pediatric hospital with a dedicated pediatric ED (43 000 annual visits). Since 2002, the institution has used a clinical effectiveness team to develop clinical standard work pathways for common conditions. Clinical standard work is an evidence-based approach to management of particular patient populations or diagnoses. Clinical pathways are designed as flowcharts or algorithms to guide provider decision-making and offer education

to learners on the evidence behind the recommendations. These pathways are linked to diagnosis-specific electronic order sets. Each pathway has up to 2 physician owners who serve as content experts and who also lead the development, implementation, and evaluation of the pathway. Specific process, outcome, and balancing measures are identified for each pathway a priori and are evaluated on a monthly basis with run charts. Currently, 67 clinical standard work pathways have been implemented at our institution. Pathways are formally reviewed on a quarterly basis to ensure that they remain consistent with current

medical literature and national guidelines.

Intervention

The clinical effectiveness team worked with a multidisciplinary stakeholder group to update our clinical pathway for children presenting with asthma exacerbations. This group included physicians and nurses from the ED and inpatient units as well as respiratory therapists, pharmacists, and information technology specialists.

Pathway modification began with a literature review of Embase, PubMed, and national guideline clearinghouses. Using a standardized process, the team of clinicians (physician pathway owners) rated the quality of the evidence and generated a series of recommendations. When possible, the method of the Grading of Recommendations, Assessment, Development and Evaluations Working Group was used. Evidence was first assessed as to whether it was from a randomized trial or cohort study. The rating was then adjusted in the following manner³³: Quality ratings were downgraded if we found that studies had serious limitations, had inconsistent results, had evidence that did not directly address clinical questions, had imprecise estimates, or if we observed substantial publication bias. Quality ratings were upgraded if we concluded that study effect sizes were large; if confounding likely resulted in underreporting the magnitude of the effect; or if a dose-response gradient was evident. When evidence was not available from the literature, recommendations were made based on local expert consensus. The team used these recommendations to modify the organizational layout and content of the multiphase pathway (ED and inpatient) and electronic order sets.

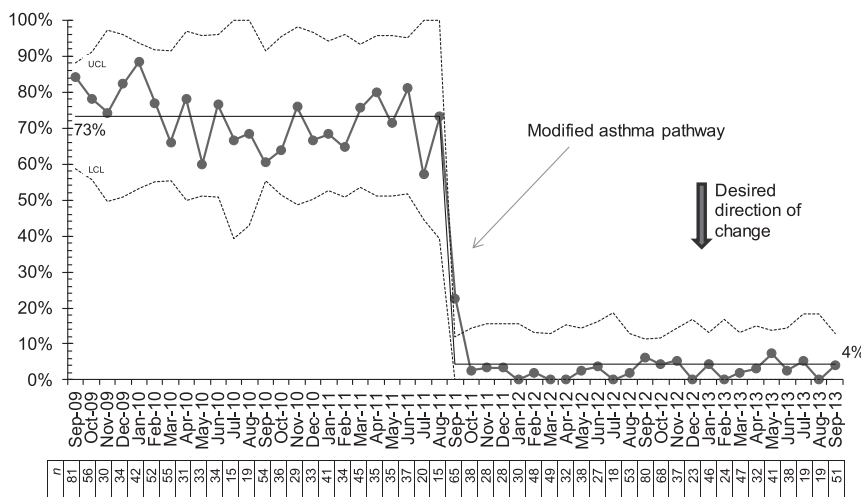


FIGURE 3
P-chart for proportion of patients with asthma receiving ipratropium bromide as an inpatient over time. LCL, lower control limit; UCL, upper control limit.

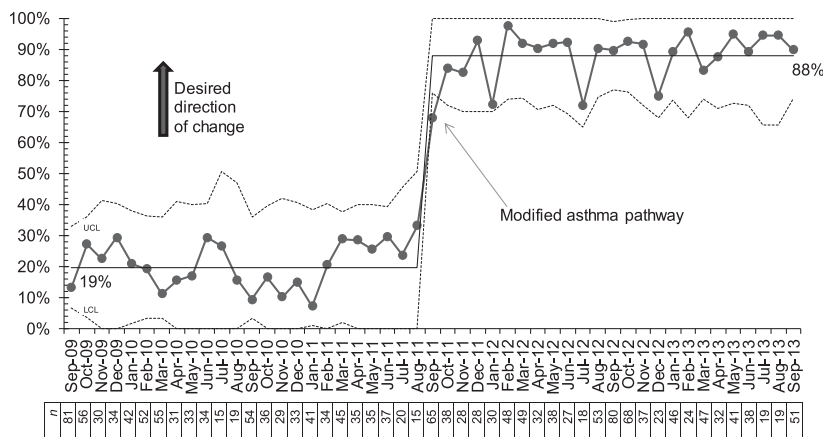


FIGURE 4
P-chart for proportion of admitted patients with asthma receiving the appropriate steroid prescription at hospital discharge. An appropriate prescription was defined as prednisone or prednisolone (2 mg/kg/d) for 5 to 10 days. LCL, lower control limit; UCL, upper control limit.

The modifications were approved during a series of meetings and subsequently built into the electronic medical record. The modified asthma pathway and electronic order sets were launched on September 5, 2011. As with previous versions of the pathway, the modified version used the Respiratory Clinical Score to guide treatment (Supplemental Fig 7). Similar to other scoring tools, the Respiratory Clinical Score is based on respiratory rate, retractions, dyspnea, and auscultation; it has a maximum score of 12. This instrument has demonstrated good interobserver agreement between

physicians, nurses, and respiratory therapists.³⁴

In addition to organizational changes such as renaming the order sets to make them easier to find and use, the pathway was modified to target specific opportunities for improvement (Table 1). For example, there were updates to the medical literature with respect to magnesium sulfate^{35–45} and ipratropium bromide^{46–52} that had yet to be put into practice at our institution. In other cases, we had specific local metrics to target for improvement such as ED length of stay (LOS)

for admitted patients with asthma and steroid prescribing patterns at the time of hospital discharge. For example, before the pathway modification, patients were often discharged from the hospital with prescriptions to complete a 2-day course of dexamethasone, similar to our practice in the ED, rather than 5 to 10 days of prednisone or prednisolone.¹⁴

Implementation of the modified pathway was led by the ED and inpatient physician pathway owners as well as respiratory therapy and clinical nursing specialists. Multiple strategies were used to support uptake and adherence. For 2 weeks before implementation, the pathway modifications were discussed at ED and inpatient provider meetings. E-mail notifications (including to physician and nurse job aids) were sent. In addition, a mandatory Web-based training module was distributed. This training was required for all ED and inpatient providers. It described all pathway modifications and included a knowledge assessment with a required minimum passing score. Finally, laminated copies of the pathway were placed outside patient rooms and in provider work areas to ensure visibility and access.

Study of the Intervention

The goal of this QI study was to assess outcomes before and after implementation of the modified asthma pathway and electronic order sets. To ensure providers were using the pathway and order sets when indicated, we monitored the percentage of eligible asthma patients each month with an asthma order set activated.

Measures

Process, outcome, and balancing measures were considered in this analysis (Table 1). Process measures were selected to reflect the evidence-based modifications made to the

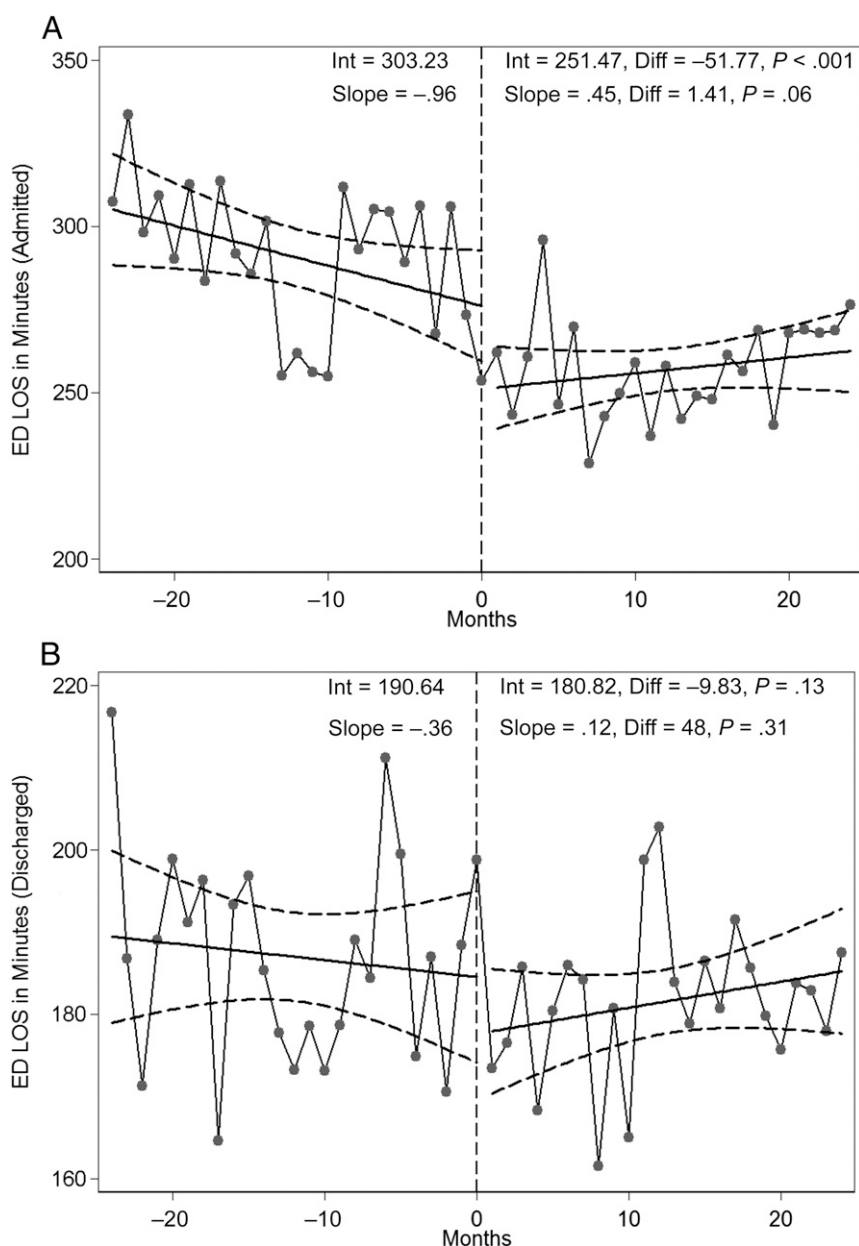


FIGURE 5
ITS results for ED LOS for (A) admitted and (B) discharged (ED-only) patients with asthma, before and after modification of the asthma pathway. Pathway modification is denoted by the dashed vertical line.

pathway and order sets. Outcome measures included LOS for both ED-only and admitted patients and were selected to determine the efficiency of care provided. Balancing measures were selected to monitor and identify any unintended consequences of modifying the asthma pathway. For example, the overall proportion of asthma admissions was monitored because 1 modification was the addition of

objective admission criteria to the ED phase of our pathway; a change in the proportion of patients admitted, particularly in conjunction with a change in unplanned returns, could signal inappropriate admission thresholds. Furthermore, unplanned returns to the ED and inpatient units were very low at baseline (<1%); an elevation might signal inappropriate discharge from the ED or inadequate steroid course for

patients who were discharged from the hospital.

Cost data were obtained from hospital administrative records. Costs were inflation-adjusted to 2013 US dollars by using the medical care component of the Consumer Price Index.⁵³ Because cost data are typically left-skewed with a few very high observations that can bias mean estimates, the top 1% of costs were truncated and assigned the value for the 99th percentile.

Analysis

Data were analyzed for 24 months before and after modification of our asthma pathway (September 2009–September 2013). Eligible children were those who presented to our ED with an asthma exacerbation from September 1, 2009, to October 1, 2013, aged 1 to 18 years, and eligible for the asthma pathway. Eligibility for pathway use included having a primary *International Classification of Diseases, Ninth Revision, Clinical Modification* diagnosis code associated with asthma (493.00, 493.01, 493.02, 493.10, 493.11, 493.12, 493.20, 493.21, 493.22, 493.81, 493.82, 493.90, 493.91, and 493.92). Exclusion criteria included acute illness such as pneumonia, bronchiolitis, or croup; chronic conditions such as cystic fibrosis and restrictive lung disease; congenital and acquired heart disease; airway issues such as vocal cord paralysis, tracheomalacia, and tracheostomy dependence; immune disorders; sickle cell anemia; and medically complex children defined as those classified as having complex chronic disease according to the Pediatric Medical Complexity Algorithm.⁵⁴

Descriptive statistics were used to compare demographic characteristics of the premodification and postmodification groups. Statistical process control (SPC) was used to analyze process measures.^{55,56} All control charts were created by using

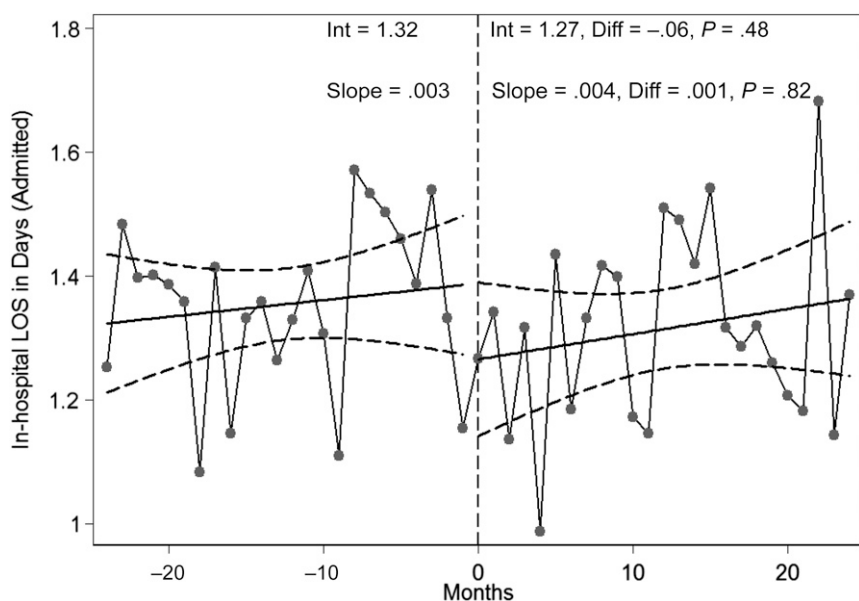


FIGURE 6
ITS results for hospital LOS for patients with asthma, before and after modification of the asthma pathway. Pathway modification is denoted by the dashed vertical line.

the QI Charts 2.0 add-on for Microsoft Excel (Process Improvement Products, Austin, TX).

For outcome measures (LOS and cost), interrupted time series (ITS) analysis was conducted by using segmented linear regression models. This analytic technique fits a separate regression line with different intercepts and slopes to the data points in each time period (before and after pathway modification) and then statistically compares the 2 intercepts and the 2 slopes based on the Wald *t* test.⁵⁷

Ethical Considerations

This study was approved under expedited review by our institution's internal review board.

RESULTS

A total of 5584 patients met eligibility criteria during the 4-year study period. There were no statistically significant differences between the premodification and postmodification groups with regard to age, sex, race/ethnicity, and insurance type (Table 2).

Process Measures

Provider adherence to the asthma pathway was high throughout the study period. We did note special cause with a shift of 8 points above the centerline immediately after pathway modification, bringing the percentage of patients with asthma with an activated order set to ~90% (Fig 1). The population of patients who were eligible for intravenous magnesium was relatively small; therefore, data for this measure were subgrouped according to quarter to improve statistical power. An increase was noted in the percentage of eligible patients with asthma receiving intravenous magnesium in the ED, with a shift in the centerline on the SPC chart after pathway modification from a baseline of 8% to 63% (Fig 2). As mentioned earlier, review of the medical literature affirmed the utility of ipratropium bromide only in the ED; therefore, we sought to decrease inpatient use of this medication. Through pathway modification and order set changes, we decreased our inpatient ipratropium bromide use from a baseline of 73% to 4% (Fig 3). Similarly, we noted improvement

and special cause variation in the percentage of patients receiving appropriate steroid prescriptions at the time of hospital discharge from a baseline of 19% to 88% (Fig 4). All SPC results were sustained for the entirety of the 2-year postmodification period.

Outcome Measures

Results from our ITS analysis demonstrated a clinically and statistically significant decrease in ED LOS for admitted patients by ~30 minutes. This decrease is likely a reflection of the admission criteria added to the pathway after 1 hour of treatment in the ED as we saw a similar decrease in the time to provider bed request.²⁰ ED LOS did not change for patients who were discharged (Fig 5). Inpatient LOS did not change significantly after the pathway modification (Fig 6).

Balancing Measures

The percentage of patients admitted with asthma remained stable (~30%), with the exception of a 4-month period of increase not temporally associated with the modification and thought to be related to poor local air quality due to wildfires (Supplemental Fig 8).²⁰ Unplanned returns to the ED and inpatient units were rare events at baseline (<1% of patients), and thus changes were monitored by using T charts. We observed no sustained changes in this measure over the 4-year study period (Supplemental Fig 9). Finally, costs of care for asthma were measured for both ED-only and admitted patients. A statistically significant difference was found in the intercept for costs among those discharged from the ED (\$59; *P* = .04), although that increase was small, representing <10% of total costs in each period. There were marginal, but not statistically significant, differences in the slopes for costs of care for ED-only patients between the premodification and

postmodification groups ($P = .08$) (Supplemental Fig 10).

DISCUSSION

In this study, SPC and ITS analyses were used to examine the relationship between modification of a well-established clinical pathway for asthma and provision of evidence-based care, efficiency (LOS), and cost in both the ED and inpatient settings in a single freestanding tertiary care pediatric hospital. We found that pathway modification, including order set redesign and provider education, improved provider adherence and subsequent delivery of evidence-based care in both the ED and inpatient settings. Furthermore, the modified pathway was associated with improved patient throughput in the ED for admitted patients, with no significant changes in overall admissions or unplanned readmissions. Importantly, our analysis included 4 years of data, and the results were sustained for the duration of the 2-year postmodification period.

In this analysis of costs, the postperiod slope had a P value of 0.08, which may suggest a marginal increase in costs for ED-only patients. This small (\$2/month) difference may have been driven by the adoption of electronic respiratory therapy charge sheets during this time period, which increased our ability to charge for provided services. Future research should assess the slope over a longer time period to assess whether this change was driven by billing or another driver of costs.

QI strategies, including care standardization through clinical pathways, improve outcomes and processes of care for asthma, at least in the short term in outpatient²³ and inpatient²⁴ settings. There is a gap in the literature regarding how to achieve provider buy-in and maintain adherence or if results can be

sustained over long periods of time. A recent study by Nkoy et al²⁵ showed sustained improvements in 8 asthma quality measures over a 5-year period after implementation of an evidence-based care process model at a pediatric tertiary care hospital; the group then disseminated the model to 7 community hospitals, with similar improvements. Our study adds to this knowledge base, demonstrating that utilization of Plan-Do-Study-Act cycles to modify well-established asthma clinical pathways is a successful approach for producing ongoing improvements in provider practice and patient outcomes that are similarly sustained over time. This outcome suggests that well-designed clinical pathways might not only be effective in acute management of pediatric illness but can be successfully modified over time to incorporate new evidence as it is produced, an important characteristic in a rapidly changing health care milieu.

Our study has limitations. First, patients were identified for analysis primarily by using *International Classification of Diseases, Ninth Revision, Clinical Modification* discharge diagnosis codes; thus, there may have been misclassification, but we expect any bias to be similar in the premodification and postmodification periods. We further refined our patient population by applying the Pediatric Medical Complexity Algorithm⁵⁴ to ensure that children with medical complexity who were ineligible for the asthma pathway were not included in the analysis.

A second limitation is that we used the Respiratory Clinical Score³⁴ rather than more widely used tools.^{58–66} Although this tool has features similar to these other well-established instruments, it is not identical, and this difference potentially limits the generalizability of our results to institutions in which other scoring systems are used.

Finally, our institution was an early adopter of care standardization and has had infrastructure in place to implement and modify clinical pathways since 2002. Over time, our culture has shifted such that providers are familiar with use of clinical pathways and electronic order sets. This infrastructure and level of provider buy-in may limit generalizability of our intervention to other institutions. We suspect that similarities in contextual factors (eg, QI leadership, culture, capability, staff motivation) between institutions as delineated in the Model for Understanding Success in Quality may be a critical factor in repeated success.⁶⁷

CONCLUSIONS

Modification of a well-established clinical pathway and electronic order set for ED and inpatient management of asthma led to immediate and sustained improvements in provision of evidence-based care and efficiency without significantly affecting costs across the continuum of care at a freestanding pediatric hospital. These findings suggest that clinical pathways can be successfully modified and implemented when new evidence becomes available, and continuous re-evaluation and modification may be an effective method for improving care over time. Contextual factors, including institutional culture and leadership support for such interventions, are important considerations for implementation success and long-term sustainability.

ABBREVIATIONS

ED: emergency department
ITS: interrupted time series
LOS: length of stay
QI: quality improvement
SPC: statistical process control

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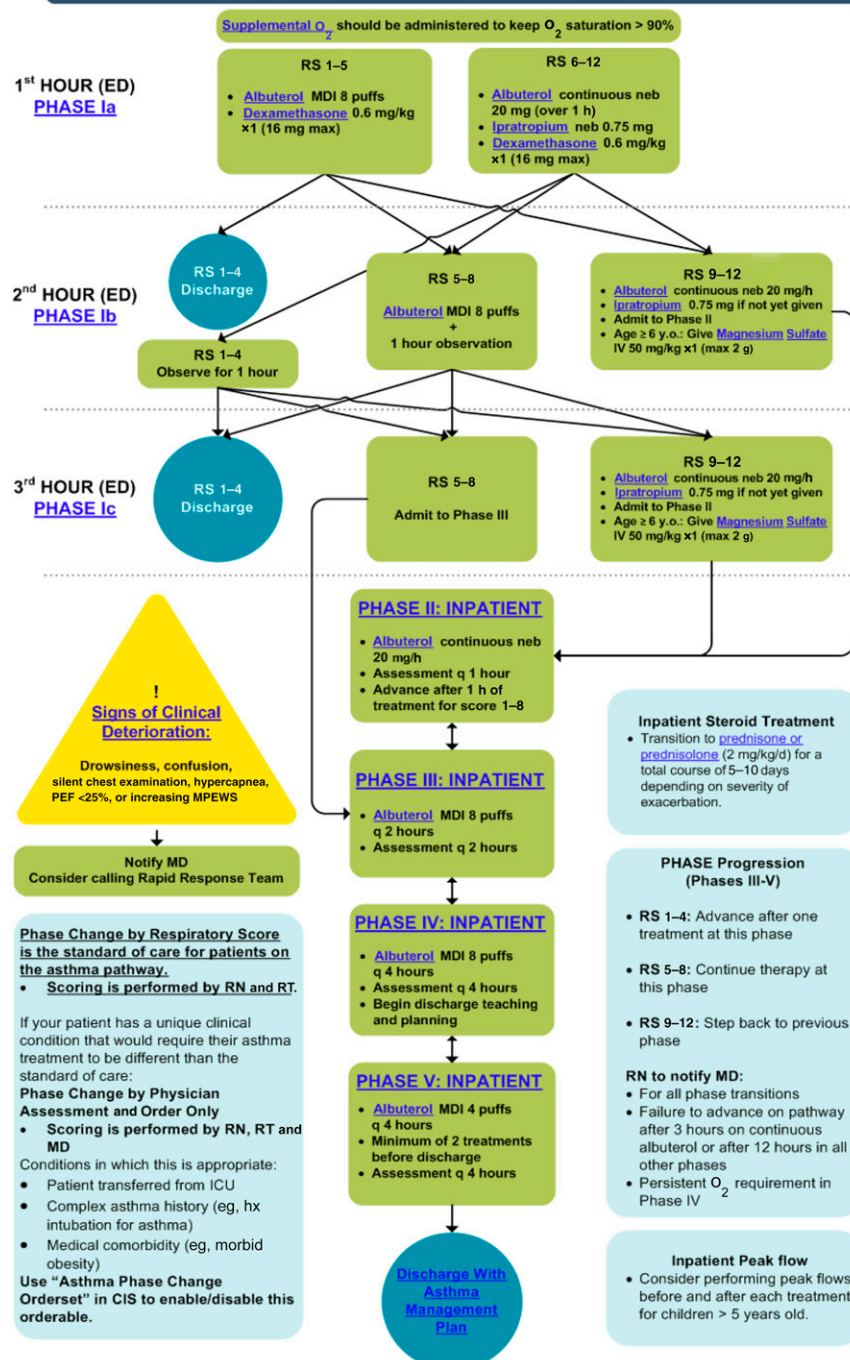
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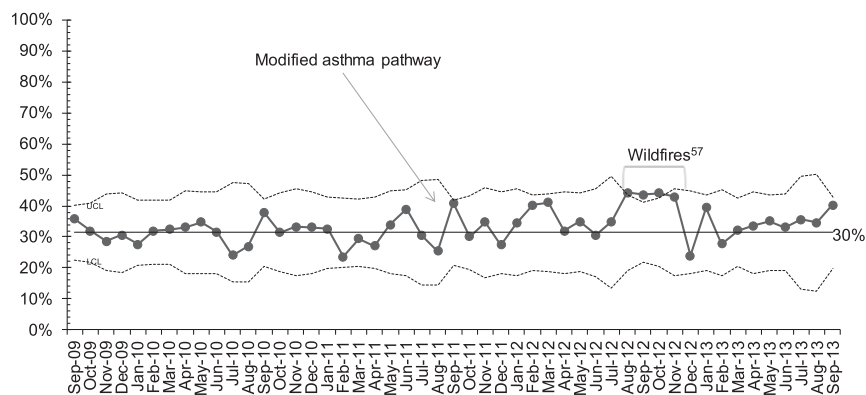
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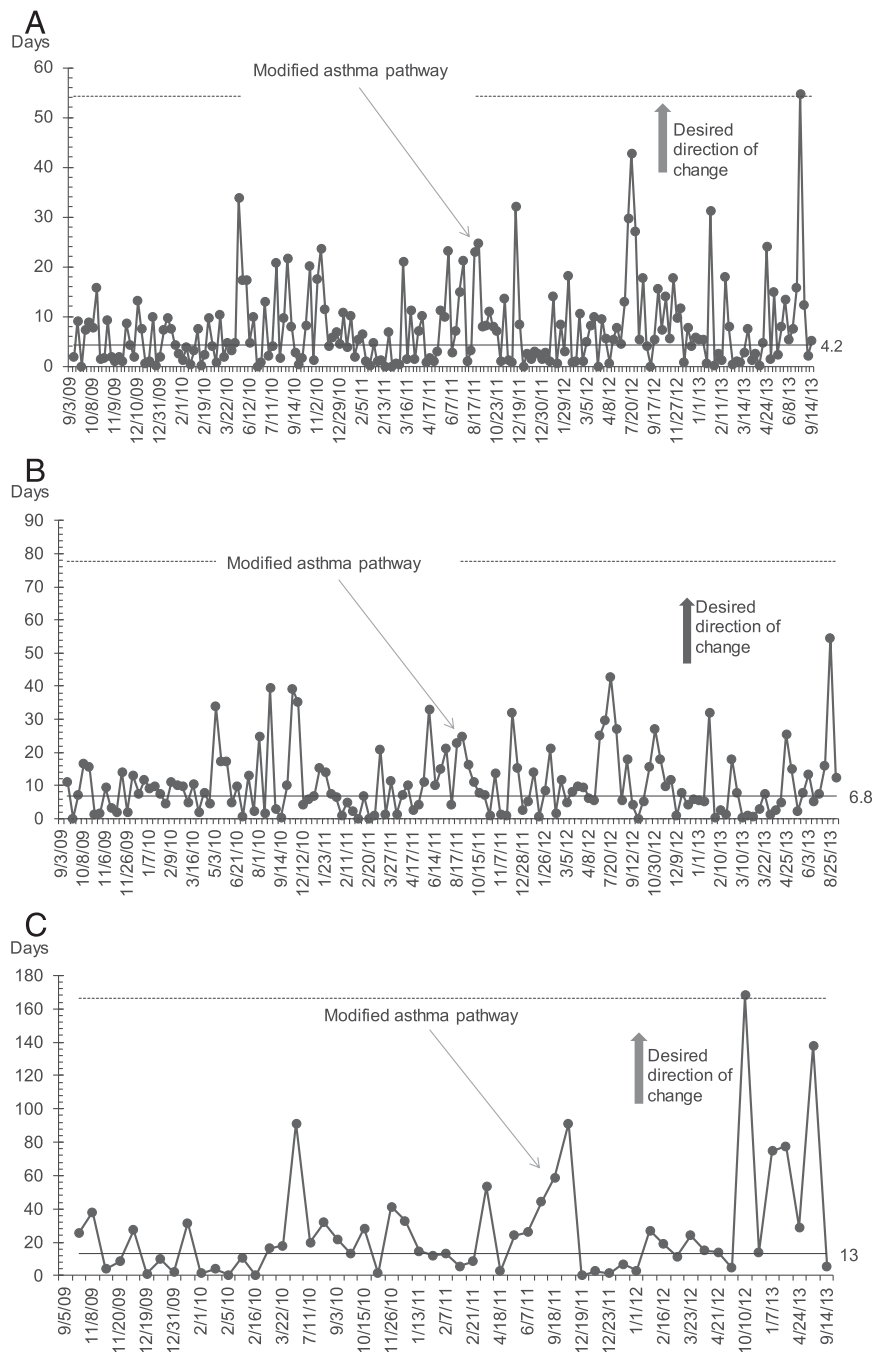
SUPPLEMENTAL FIGURE 7

Modified asthma pathway. MD, medical doctor; MDI, metered dose inhaler; MPEWS, Modified Pediatric Early Warning Score; O₂, oxygen; PEF, peak expiratory flow; RN, registered nurse; RS, respiratory score; RT, respiratory therapist.



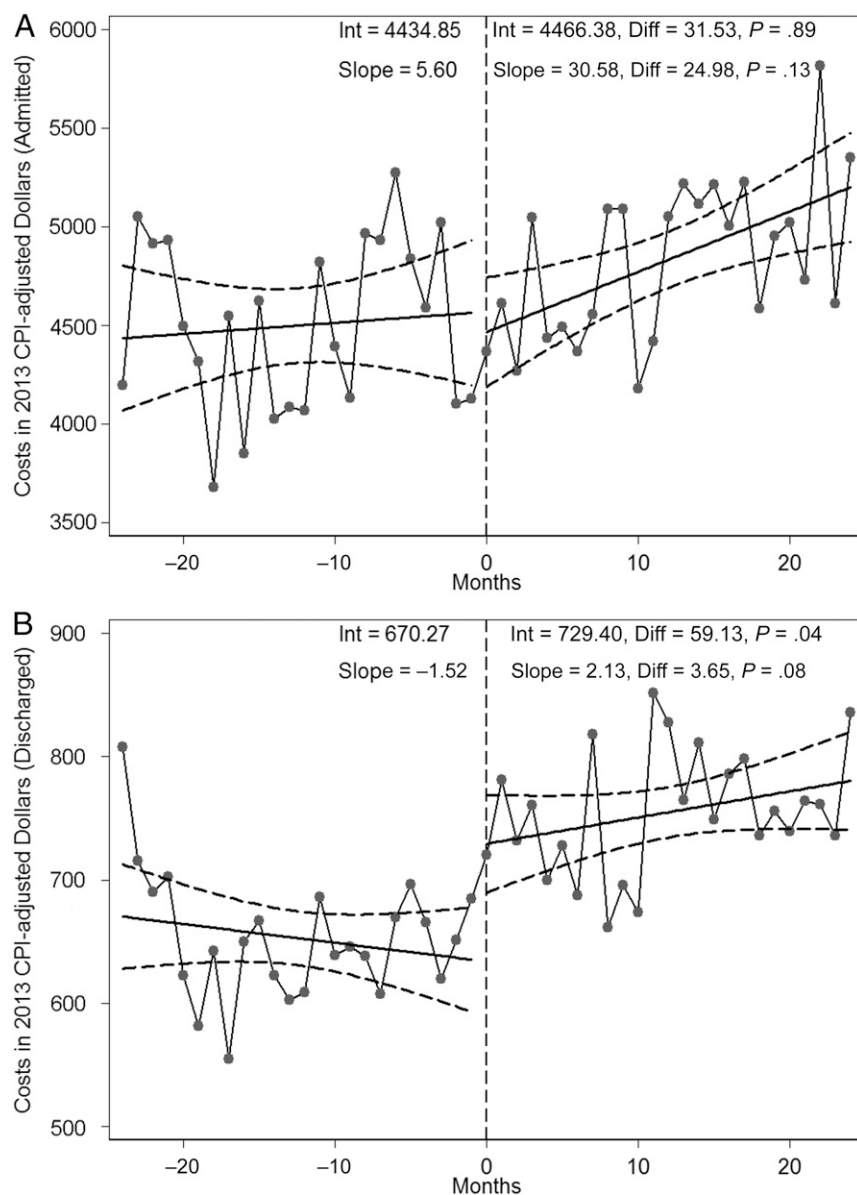
SUPPLEMENTAL FIGURE 8

P-chart for proportion of patients admitted with asthma over time. LCL, lower control limit; UCL, upper control limit.



SUPPLEMENTAL FIGURE 9

T-chart for days between all (A) 72-hour ED returns, (B) 72-hour ED returns with discharge, and (C) 72-hour ED returns with admission.

**SUPPLEMENTAL FIGURE 10**

ITS results for inflation-adjusted costs of care for (A) admitted and (B) discharged (ED-only) patients with asthma, before and after modification of the asthma pathway. Pathway modification is denoted by the dashed vertical line. CPI, Consumer Price Index.