

An Asthma Population Health Improvement Initiative for Children With Frequent Hospitalizations

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OBJECTIVES: A relatively small proportion of children with asthma account for an outsized proportion of health care use. Our goal was to use quality improvement methodology to reduce repeat emergency department (ED) and inpatient care for patients with frequent asthma-related hospitalization.

METHODS: Children ages 2 to 17 with ≥ 3 asthma-related hospitalizations in the previous year who received primary care at 3 in-network clinics were eligible to receive a bundle of 4 services including (1) a high-risk asthma screener and tailored education, (2) referral to a clinic-based asthma community health worker program, (3) facilitated discharge medication filling, and (4) expedited follow-up with an allergy or pulmonology specialist. Statistical process control charts were used to estimate the impact of the intervention on monthly 30-day revisits to the ED or hospital. We then conducted a difference-in-differences analysis to compare changes between those receiving the intervention and a contemporaneous comparison group.

RESULTS: From May 1, 2016, to April 30, 2017, we enrolled 79 patients in the intervention, and 128 patients constituted the control group. Among the eligible population, the average monthly proportion of children experiencing a revisit to the ED and hospital within 30 days declined by 38%, from a historical baseline of 24% to 15%. Difference-in-differences analysis demonstrated 11.0 fewer 30-day revisits per 100 patients per month among intervention recipients relative to controls (95% confidence interval: -20.2 to -1.8 ; $P = .02$).

CONCLUSIONS: A multidisciplinary quality improvement intervention reduced health care use in a high-risk asthma population, which was confirmed by using quasi-experimental methodology. In this study, we provide a framework to analyze broader interventions targeted to frequently hospitalized populations.

abstract



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DOI: <https://doi.org/10.1542/peds.2019-3108>

Accepted for publication Apr 27, 2020

Health systems, payers, and policy leaders are seeking strategies to reduce unnecessary health care use and costs. Because a small subset of the population accounts for a disproportionate amount of health care use and costs, both in adult

populations^{1,2} and in children,^{3,4} one commonly employed strategy to decrease use and cost is to identify high-using populations and tailor interventions to their needs. Although there are data to justify such an approach in adult populations,² there is

To cite: Kenyon CC, Strane D, Floyd GC, et al. An Asthma Population Health Improvement Initiative for Children With Frequent Hospitalizations. *Pediatrics*. 2020;146(5):e20193108

a paucity of such data in pediatrics, as well as potentially important missed opportunities associated with not investing in lower-risk populations.⁵ Thus, empirical assessments of the effectiveness of different population health strategies are critical to determine where to invest limited resources.

Pediatric asthma represents an important proof of concept for this strategy because asthma emergency department (ED) visits and hospitalizations are theoretically preventable, and previous work has revealed that 5% of pediatric patients with asthma account for up to 50% of costs related to the diseases.⁶ Despite this, researchers of only a few previous studies have attempted to target frequently hospitalized pediatric populations with interventions.^{7–11} This previous work has revealed that focused asthma care education and community support can reduce health care use in pediatric high-risk populations, but this work has been limited to assessments of interventions without control groups, which are particularly important for populations with high health care use.¹² For these reasons, researchers investigating population health initiatives need to rigorously evaluate effectiveness beyond basic pre-post assessments.

In this study, pediatric patients who had been hospitalized for asthma exacerbations ≥ 3 times within the previous year were enrolled in a bundle of 4 coordinated services that were not previously administered in a consistent and coordinated fashion. Existing data from our institution revealed that nearly 25% of children with this degree of hospital use had an ED or hospital revisit for asthma within 30 days of discharge. We aimed to decrease repeat 30-day ED and inpatient revisits for patients with frequent asthma-related hospitalization by 50% in 1 year through implementation of

a coordinated asthma discharge bundle.

METHODS

Study Design and Population

This was a longitudinal quality improvement (QI) initiative supplemented with an assessment of robustness by using difference-in-differences analysis. The target cohort was children hospitalized for asthma ≥ 3 times in the previous year at a large academic children's hospital from May 2016 to April 2017. Children ages 2 to 17 were eligible for the intervention if they were admitted to the inpatient setting for asthma to the same hospital for the third or more time in the preceding 365 days and received their primary care at 1 of 3 inner-city primary care centers affiliated with the hospital. Both qualifying and historical inpatient admissions were considered "for asthma" if the care team initiated the inpatient asthma pathway protocol order during the admission. Exclusion criteria included patients with chronic comorbid respiratory conditions, such as restrictive lung disease or cystic fibrosis. Otherwise eligible children who received their primary care in the same region but not at the 3 affiliated inner-city practices were not initially included in the intervention because they did not have access to the clinic-based community health worker (CHW) component of the intervention.

Intervention

Providers from hospitalist, primary care, ED, pulmonary, allergy, social work, case management, respiratory care, nursing, and QI backgrounds engaged in a multidisciplinary process analysis to identify drivers of repeat asthma hospitalization. Several existing but previously fragmented evidence-based practices were identified as a potential bundle of care services to be coordinated at the time of qualifying hospitalization.

These included (1) replacing a group asthma education class with tailored bedside asthma education^{10,13–15} that uses a modified asthma risk screener¹⁶; (2) referral to the Community Asthma Prevention Program (CAPP), an asthma CHW program that includes home visits and clinic-based care navigation at the 3 inner-city primary care sites¹⁷; (3) facilitated discharge medication filling at the outpatient pharmacy within the hospital^{18,19}; and (4) expedited follow-up in allergy or pulmonary specialty clinics within 30 days of hospital discharge when appropriate.^{20,21} These interventions were initially tested and implemented in May 2016.

QI Methods

We formed subgroups focused on each bundle component consisting of multidisciplinary team members and frontline clinicians. We used the plan-do-study-act model to facilitate tests of change, which included personnel education, use of new electronic health record (EHR) reporting tools and alerts, and changes to scheduling procedures. The team identified process measures to track completion of each bundle component documented within the EHR. Run charts for each discrete measure were developed and monitored at twice-monthly meetings of the multidisciplinary team. Additional QI methods are described in the Supplemental Information.

Process Measures

For inpatient risk screener completion and tailored education, 2 asthma nurse champions and 1 respiratory therapist completed a care coordination note documenting bundle enrollment during the qualifying hospitalization. For CAPP referral, bundle enrollment was considered complete when a CHW performed his or her first home-based assessment and added his or her name to the patient's EHR "Care Team." The process measure for

facilitated discharge medication filling was electronic prescription of discharge medication to the hospital's outpatient pharmacy. Lastly, for expedited specialty follow-up, we tracked the proportion of children referred to either allergy or pulmonology who were scheduled in those clinics within 30 days of qualifying hospital discharge. Rationale for the selection of process metrics is included in the Supplemental Information.

Completion of either tailored bedside education during qualifying admission or enrollment in the CAPP within 30 days of index hospital discharge constituted enrollment in the care bundle because these 2 components represented robust and timely efforts to identify reasons for frequent emergency care use and mitigate risk through targeted education and referrals. Because we were using existing clinical staff who were not available on the weekends, our a priori target goals for percentage enrolled in the individual bundle components was 70%, except for CAPP enrollment, which was 50%. This lower threshold reflects the difficulty scheduling and completing home visits within 30 days of referral.

Comparison Group

The comparison group for this analysis was children who met all intervention inclusion criteria except that they received their primary care outside of the 3 eligible inner-city practices. Control group participants were not targeted for tailored bedside education or enrollment in the CAPP but may have received facilitated discharge medication filling or expedited specialist follow-up independent of the efforts of this initiative. Instead of tailored education, children in the comparison group continued to receive a group asthma education class that was part of the hospital's standard care for all admitted children with asthma.

Outcomes

The primary outcome was the monthly proportion of children with a 30-day revisit to either the ED or the inpatient setting for asthma after a qualifying hospitalization (third or more asthma admission in the 365 days preceding admission). We also assessed 3-month revisits as a secondary outcome in the difference-in-differences analysis and converted these estimates to numbers of monthly revisits per 100 patients per month.

Covariates

Covariates included age, sex, race and/or ethnicity, number of asthma-related ED visits and hospitalizations in previous 365 days, and number of complex chronic conditions.²²

Statistical Analysis

We used run charts to track process measures and p-charts to track outcome measures for bundle-eligible children on a monthly basis over the course of the study year. The baseline rate for each process measure was calculated as the median of each measure for the 16 months preceding the bundle launch (January 2015 to May 2016), except for tailored inpatient education, a newly delivered process with a median initially calculated over the study year. The baseline rate for the outcome measure was the mean calculated over the 16 preceding months. Signal of change or special cause variation was determined by using widely cited run and control chart rules for detecting a systematic process change via a trend (≥ 5 consecutive points increasing or decreasing for run charts and 6 points for p-charts) or a run (≥ 6 consecutive points above or below the median for run charts and 8 points for p-charts)^{23–25} in the setting of a targeted intervention. Process change was noted on charts when either signal of change or special

cause variation was detected in concert with known system change.

To estimate the association between enrollment in the intervention and monthly revisits, we used the quasi-experimental method known as difference in differences.²⁶ It serves as an improvement over traditional pre-post QI analyses because it compares changes among those in an intervention group to changes among those in a control group. This method was used to validate findings from the 30-day revisit longitudinal run charts.

In the first model, we examined revisits in the 1 month after intervention enrollment, whereas in the second model, we examined revisits in the 3 months after enrollment in the intervention to assess for enduring intervention effects. To obtain difference-in-differences estimates for each of these outcomes, we compared changes in hospital revisits among children who received the intervention to changes among children who did not receive the intervention. From these models, we obtained difference-in-differences estimates, which are reported with 95% confidence intervals (CIs) for the average number of revisits per patient per month.

QlikView (Qlik Technologies, King of Prussia, PA) dashboards were developed and used as longitudinal run charts and difference-in-differences analyses were conducted by using SAS 9.4 (SAS Institute, Inc, Cary, NC). The study was determined not to be human subjects research by the local institutional review board.

RESULTS

From May 1, 2016, to April 30, 2017, 207 patients met our inclusion criteria with 3 hospital admissions for asthma in the past year. Of these, 79 participants received their primary care at an eligible center and were enrolled in the "High-Utilizer Bundle." In total, 128 participants who did not

receive their primary care at an eligible center served as controls. Overall, 90.3% of participants were Black and 84.1% had public insurance. Both the intervention and control cohorts averaged 3.2 asthma hospitalizations in the one-year preintervention period. Additional participant demographics and previous health care use are provided in Table 1. Of those enrolled, 48 received tailored bedside education and 41 were enrolled in CAPP within 30 days of discharge; 10 participants received both. Receipt of the other bundle components is found in Table 2.

Process Measures

Figure 1 reveals the proportion of eligible participants who received each of the 4 bundle components from May 2016 to April 2017. Inpatient risk screening and tailored education generally increased through the intervention with signal detected 6 months after the intervention start (November 2016) and first exceeded the goal threshold of 70% in January 2017 (Fig 1A).

The proportion of patients enrolled by the CAPP within 30 days of discharge increased above the historical baseline for each month of

TABLE 2 High-User Bundle Components Received

Intervention Component	Intervention, <i>n</i> = 79, <i>n</i> (%)	Control, <i>n</i> = 128, <i>n</i> (%)
Tailored bedside education	48 (61)	9 (7)
CAPP enrollment	41 (52)	0 (0)
Discharge medications	41 (52)	74 (58)
Expedited specialty follow-up	13 (16 ^a)	13 (10 ^a)

^a This percentage represents the percentage of intervention and control group participants with completed specialty follow-up within 30 d. Only a subset of participants were referred to and subsequently scheduled for specialty follow-up within this window.

the intervention, with signal detected in the first month (Fig 1B).

The percentage of children whose medications were sent to the outpatient pharmacy varied around the baseline for the first 5 months after the initiative began. In the following 7 months, the proportion of discharged medications increased but without signal (Fig 1C).

Scheduled visits for specialty clinic within 30-days of discharge varied over the first 3 intervention months before exceeding the historical average for 8 of the 9 following months without signal (Fig 1D).

Outcome Measures

Figure 2 reveals the longitudinal trends in 30-day hospital revisits for asthma from January 2015 to April 2017, which includes the intervention interval and 16 months preceding the

initiation of the bundle. Among eligible participants, overall 30-day revisit rates were 24% in the 16 months preceding the initiative and 15% in the year after implementation. For control participants, the overall 30-day revisit rates were 15% in the 16 months before and 21% in the year after the bundle's start. For the intervention cohort, special cause variation was detected at January 2017, 9 months after the intervention start.

Difference-in-Differences Analyses

Using the difference-in-differences estimates reported in Table 3, we confirm our findings from QI charts. The reduction in revisits within the first month after intervention enrollment was greater by 11.0 revisits per 100 patients among the intervention group (95% CI: −20.2 to −1.8; *P* = .02) relative to the comparison group. In the 3 months after enrollment, the reduction in revisits per 100 patients per month was greater by 6.4 among those receiving the intervention (95% CI: −12.2 to −0.6; *P* = .03) relative to the comparison group.

DISCUSSION

In this asthma population health improvement initiative, we enrolled children with multiple asthma hospitalizations in the previous year into a bundle of evidence-based asthma services. Using QI methodology, we show that bundle enrollment was associated with a decline in 30-day average monthly

TABLE 1 Overall Cohort Description and Comparison of Enrolled Participants to Nonenrolled Participants

Characteristic	Overall, <i>N</i> = 207	Not Enrolled, <i>n</i> = 128 (62%)	Enrolled, <i>n</i> = 79 (38%)
Age, <i>n</i> (%)			
0–4	80 (39)	50 (39)	30 (38)
5–11	90 (44)	54 (42)	36 (46)
≥12	37 (18)	24 (19)	13 (16)
Male sex, <i>n</i> (%)	120 (58)	70 (55)	50 (63)
Race, <i>n</i> (%)			
Black	187 (90)	112 (88)	75 (95)
White and other	20 (10)	16 (13)	4 (5)
Hispanic, <i>n</i> (%)	12 (6)	1 (1)	11 (9)
Public insurance, <i>n</i> (%)	174 (84)	105 (82)	69 (87)
In-network primary care, <i>n</i> (%)	130 (63)	51 (40) ^a	79 (100)
Complex chronic conditions, <i>n</i> (%)			
1	167 (83)	103 (82)	64 (83)
≥2	38 (17)	25 (18)	13 (17)
Asthma ED visits in previous year, <i>n</i> , mean (SD)	1.2 (1.4)	1.1 (1.4)	1.3 (1.4)
Asthma hospitalizations in previous year, <i>n</i> , mean (SD)	3.2 (0.6)	3.2 (0.5)	3.2 (0.8)

^a Includes in-network primary care patients other than those in the 3 inner-city practices.

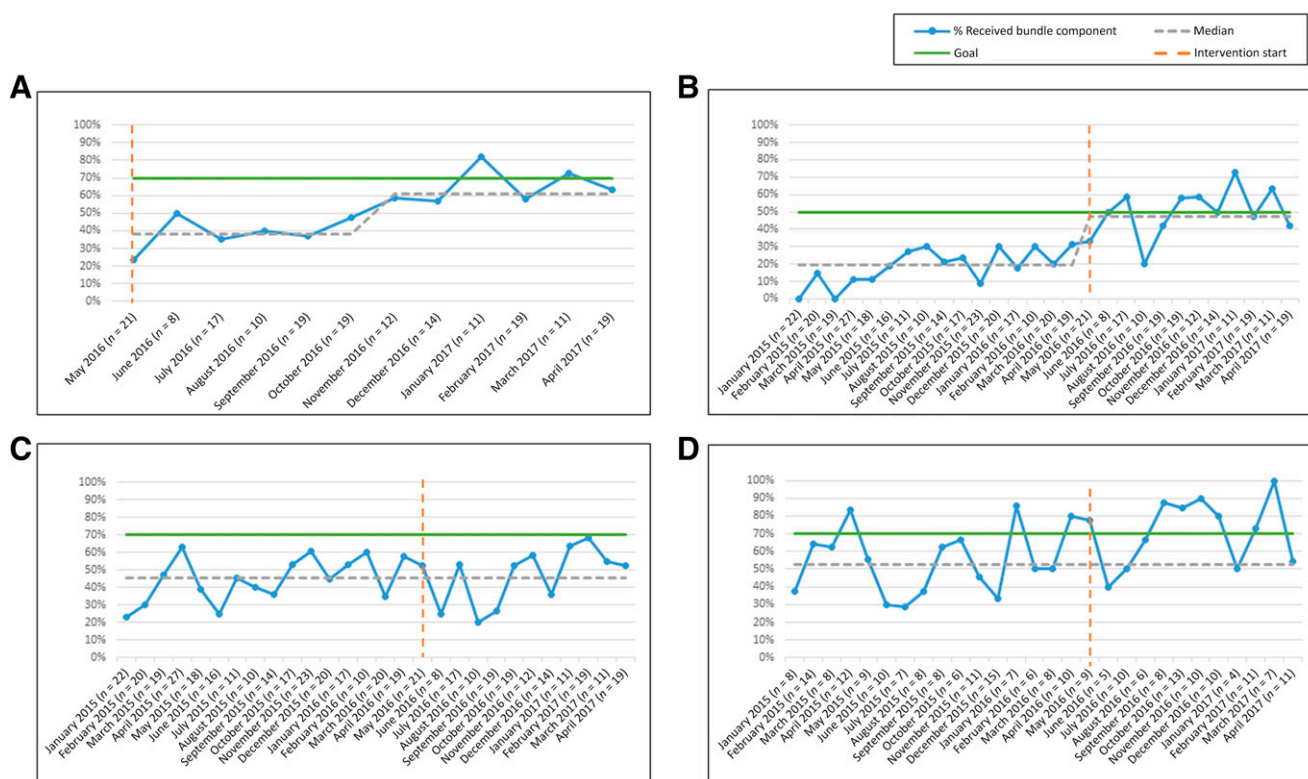


FIGURE 1

Process measure run charts demonstrating the monthly proportion of eligible children with ≥ 3 yearly inpatient admissions who received the individual bundle components. A, Proportion who received inpatient tailored asthma education. Only the 12 months after the start of the QI initiative are shown because this specific process did not exist in the preceding year. B–D, Monthly proportions of those who received the corresponding process measure for 16 months before and 12 months after the start of the QI initiative. The x-axis of each panel includes the denominator: the number of bundle-eligible patients (patient level). B, Proportion who were enrolled by the CAPP within 30 days of hospital discharge. C, Proportion who had discharge medications e-prescribed to the hospital outpatient pharmacy. D, Proportion who were scheduled with specialist follow-up within 30 days of discharge for those who were referred. The x-axis has different denominators because the measure pertains to the subset of the eligible population referred. Notable tests of change included (1) dedicated education about bundle components to inpatient teams (May 2016), (2) addition of a CAPP referral order to the EHR inpatient preference list (June 2016), and (3) addition of a best practice alert to the EHR that launched during a qualifying hospital admission, notifying the frontline clinical staff of a patient's hospitalization history and bundle eligibility as well as instructions to send discharge medications to the hospital's outpatient pharmacy, a link to enter CAPP referral, and a link to an expedited specialty follow-up order (January 2017).

revisits of 38%. In addition, this decline in average monthly revisits was verified by comparing enrolled participants with a contemporaneous comparison group by using a quasi-experimental design. These findings reveal a robust effect of a population health initiative using QI methods to streamline and coordinate 4 intervention components that are either evidence based or highly recommended for families of children with high-risk asthma.

Recently published analyses from large health system efforts to improve care and reduce inpatient bed days by using care coordination have revealed mixed findings.^{27,28} The

demonstrated effect of this intervention is likely a result of both the effectiveness of the individual intervention components and the enhanced coordination between disciplines targeted at children with one specific condition. With respect to the intervention components, the 2 primary intervention strategies (individualized bedside education and CHW-delivered home visits) have both demonstrated efficacy in clinical trials.^{10,13–15,17} Several observational studies support facilitated discharge medication filling,^{18,19} and consensus guidelines support arranging outpatient specialist follow-up for children with multiple

hospitalizations.^{20,21} Although only a small proportion of children received all bundle components, the 2 major intervention strategies are supported by the strongest evidence, and both involved substantial care coordination activities by a multidisciplinary team. Appointing a team or caseworker to care coordination activities at hospital discharge is a strategy to prevent readmission that is supported by both a recent systematic review²⁹ and meta-analysis³⁰ on this subject.

The current initiative differs from previous studies in that it used a QI approach to hone and iterate several

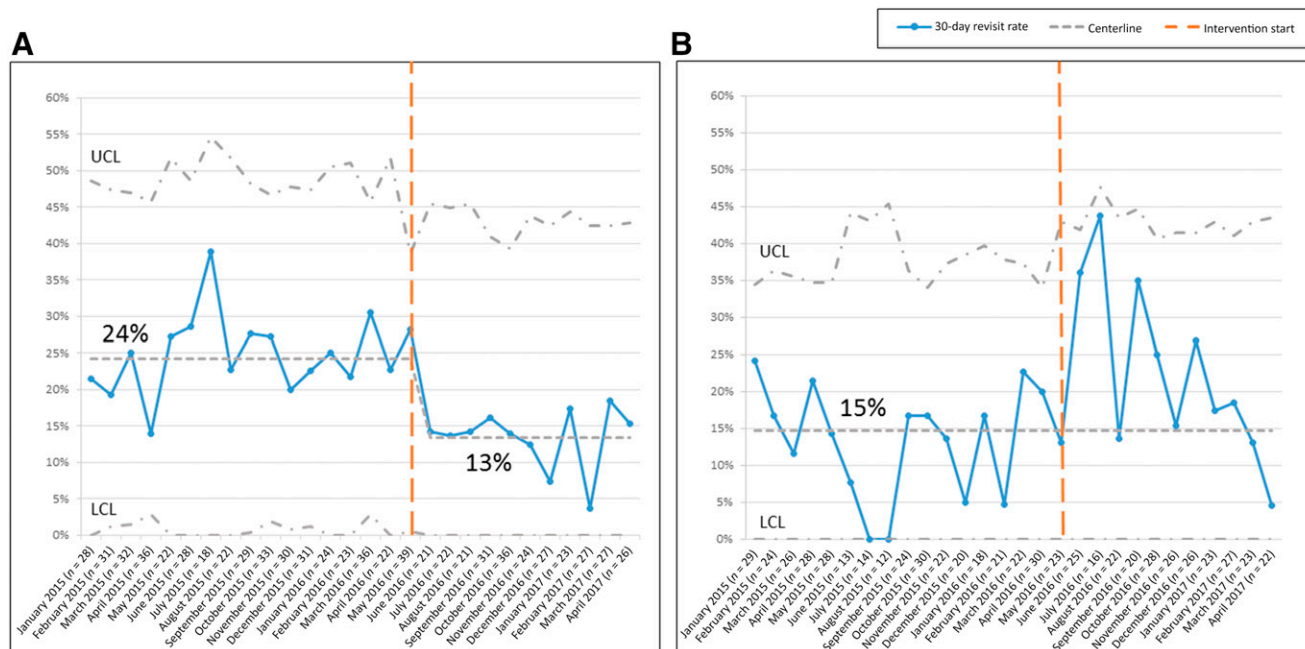


FIGURE 2

Outcome measure p-charts. A, Proportion of children with asthma-related revisit rate to either an ED or inpatient setting within 30 days of discharge for bundle-eligible patients. B, Proportion of children with asthma-related revisit to either an ED or for bundle-ineligible patients who received primary care at an un-affiliated center. The x-axis includes total monthly asthma-related visits (visit level). LCL, lower control limit; UCL, upper control limit.

existing but previously nontargeted and fragmented health system interventions. Using QI methodology, we were able to assess adoption of the bundle interventions and effect on outcomes over time. We were able to demonstrate relatively consistent improvement in bundle enrollment for the 2 main components of the bundle, tailored inpatient education and enrollment in the CAPP. As with any QI initiative, not all process measures moved robustly nor in concert. Facilitated discharge

medication filling and expedited specialty follow-up varied considerably in the first 5 months, although each had only 1 month below the historical average in the last 7 months of the intervention. With regard to the intervention group's 30-day revisit rate, we observed a centerline shift one month into the intervention. There were no other contemporaneous initiatives focused on high-risk asthma patients in these 3 clinics, and the team targeted children with the highest use

of care, which may explain the early signal for impact as bundle enrollment increased. Given the sustained decrease in revisits seen over the first 12 months of the intervention, we subsequently expanded eligibility beyond the 3 inner-city clinics. Our ongoing data collection for this combined cohort reveals sustained impact on revisits after the reporting period of this analysis (data are not shown).

Given that populations with high health care use tend to have transient health care needs that often lead to their high use only for a limited period of time,¹² we felt that it was important to include a contemporaneous and comparable control group in the intervention evaluation. As demonstrated in Table 1, control participants were similar with respect to race, insurer, and previous-year asthma emergency care use. Although their 30-day revisit rates were lower at baseline, our difference-in-differences

TABLE 3 Results of Difference-in-Differences Models

	<i>n</i>	Mean Monthly No. Revisits per 100 Patients		Difference-in-Differences Estimate (95% CI)	<i>P</i>
		One Year Before Enrollment Date	One Month After Enrollment Date		
Model 1					
Intervention	79	8.4	6.3	−11.0 (−20.2 to −1.8)	.02
Control	128	7.4	16.4		
Model 2 ^a					
Intervention	79	8.4	3.4	−6.4 (−12.2 to −0.6)	.03
Control	128	7.4	8.9		

^a The values for model 2 indicate "One Year Before Enrollment Date" and "Three Months After Enrollment Date."

analyses reveal a significant decrease in 30- and 90-day revisits between the intervention and comparison groups before and after intervention implementation, supporting the robustness of our QI results.

As pediatric health systems and population health initiatives become more strategic in their investments and initiatives, robust evaluations of differing population health strategies are critical to identifying which segments of the population are likely to have the greatest outcome benefit. Our work reveals that a targeted asthma program can reduce high health care use, but these reductions must be balanced with investments associated with establishing such a program. In particular, it will be important to engage payers in discussions as to how best support this work, whether it be through bundled payments, up-front investment in population health management, or other avenues. Post hoc analysis revealed that as a group, eligible participants experienced nearly 2 fewer rehospitalizations per month in the intervention year compared to the 16-month baseline; robust cost-effectiveness analysis, however, was beyond the scope of this report.

There are several other important limitations to consider. First, all patients in the project were enrolled at one academic medical center, limiting the generalizability of the

results. However, the bundle components were generally small changes to existing clinical workflows and were implemented with existing clinical staff, making them more likely to be reproducible. That said, certain bundle components were relatively personnel intensive, such as the tailored inpatient education and CHW intervention. We were able to repurpose nursing and respiratory therapist time previously assigned to monitor compliance with the now retired Joint Commission metrics for the tailored bedside component of this initiative, but we acknowledge that all institutions may not have existing CHW programs. Third, our initial methodology used a longitudinal QI approach, which did not translate into a pristine quasi-experimental difference-in-differences analysis. For instance, participants in both the intervention and control groups were eligible to receive 2 of the bundle components, so a portion of the control group was partially exposed to bundle components. Additionally, given the sample size, we were unable to perform subanalyses to try to determine the differential effects of the various intervention components, which would help target future efforts. A sufficiently large randomized controlled trial with factorial design could be used to best assess component effects, although this approach would be less feasible within a QI framework.

CONCLUSIONS

The findings from this study reveal that a multidisciplinary QI initiative can reduce ED and hospital revisits in a frequently hospitalized pediatric asthma population. Because population health interventions for high-risk cohorts are often validated through pre-post assessments, this intervention can be used to supply a structure for how to robustly evaluate QI projects outside of a randomized controlled trial.

ACKNOWLEDGMENTS

We acknowledge Charmane Braxton, Elizabeth Brooks, JoeyLynn Coyne, Daria Ferro, Sarah Henrickson, Ron Keren, Maureen McCloskey, Pamela Palladino, Carmen Perez, Maura Powell, Ashwini Reddy, Rose Stinson, Levon Utidjian, and Marcia Winston, who were integral to the design and execution of the intervention. The study team acknowledges Genevieve Pham-Kanter, PhD, for her assistance in developing the data analysis strategy.

ABBREVIATIONS

CAPP: Community Asthma Prevention Program
CHW: community health worker
CI: confidence interval
ED: emergency department
EHR: electronic health record
QI: quality improvement

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PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

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FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: Dr Kenyon's time on this project was supported by a K award from the National Heart, Lung, and Blood Institute (K23HL136842).

POTENTIAL CONFLICT OF INTEREST: Dr DaVeiga is a current employee of Teva Pharmaceutical Industries, Ltd, and her affiliation during the study period was as a full-time employee of the Children's Hospital of Philadelphia; the other authors have indicated they have no potential conflicts of interest to disclose.

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Pediatrics 2020;146;

DOI: 10.1542/peds.2019-3108 originally published online October 1, 2020;

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