Improving Pediatric Asthma Care and Outcomes Across Multiple Hospitals

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abstract

BACKGROUND AND OBJECTIVES: Gaps exist in inpatient asthma care. Our aims were to assess the impact of an evidence-based care process model (EB-CPM) 5 years after implementation at Primary Children’s Hospital (PCH), a tertiary care facility, and after its dissemination to 7 community hospitals.

METHODS: Participants included asthmatics 2 to 17 years admitted at 8 hospitals between 2003 and 2013. The EB-CPM was implemented at PCH between January 2008 and March 2009, then disseminated to 7 community hospitals between January and June 2011. We measured compliance using a composite score (CS) for 8 quality measures. Outcomes were compared between preimplementation and postimplementation periods. Confounding was addressed through multivariable regression analyses.

RESULTS: At PCH, the CS increased and remained at >90% for 5 years after implementation. We observed sustained reductions in asthma readmissions (P = .026) and length of stay (P < .001), a trend toward reduced costs (P = .094), and no change in hospital resource use, ICU transfers, or deaths. The CS also increased at the 7 community hospitals, reaching 80% to 90% and persisting 2 years after dissemination, with a slight but not significant readmission reduction (P = .119), a significant reduction in length of stay (P < .001) and cost (P = .053), a slight increase in hospital resource use (P = .032), and no change in ICU transfers or deaths.

CONCLUSIONS: Our intervention resulted in sustained, long-term improvement in asthma care and outcomes at the tertiary care hospital and successful dissemination to community hospitals.

Asthma is the most common reason for preventable emergency department (ED) and hospital admissions among children in the United States.1-3 In 2009, >679 000 children with asthma were admitted to the ED or hospital.1 Readmission rates of children to the ED or hospital are high and are associated with substantial health care costs.2-4 Despite a major burden, significant gaps exist between the evidence of best asthma care practices and the actual care for children hospitalized with asthma.5-8 Multiple quality improvement (QI) efforts to improve inpatient asthma care for children have been reported, but a positive impact on asthma outcomes is often not demonstrated.3,9-18 No data exist about the sustainability or long-term impact of QI interventions. Furthermore, most of the successful pediatric inpatient asthma interventions are implemented at a tertiary care pediatric centers, with little information available about dissemination to community hospitals.19-23

We previously reported suboptimal asthma care quality at Primary Children’s Hospital (PCH),8 a tertiary care children’s hospital, and...
a significant improvement in quality of care with reduction in asthma readmissions 2 years after implementation of an evidence-based asthma care process model (EB-CPM).21

Because of suboptimal baseline asthma care quality findings at community hospitals and the desire to improve care throughout the region, the specific aims of this study were twofold: to evaluate the 5-year (or long-term) impact after EB-CPM implementation at PCH and to determine the impact of disseminating the EB-CPM to 7 community hospitals. Specifically, we sought to assess changes from baseline in provider compliance with evidence-based (EB) asthma inpatient quality measures and asthma hospitalization outcomes. Our primary outcome was 6-month ED or hospital asthma readmission, consistent with our previous work,21 and the current aim to assess long-term EB-CPM impact at PCH. Secondary outcomes were length of stay (LOS), costs, hospital resource use, ICU transfer after inpatient admission, and death.

METHODS

Setting

Our study included 8 Intermountain Healthcare hospitals. Intermountain Healthcare is a regional, not-for-profit integrated health care delivery system, with 22 hospitals and 160 clinics and urgent care facilities located in Utah and southeastern Idaho,24 providing health care to ∼1 680 000 patients. Intermountain Healthcare serves ∼60% of Utah’s 2.8 million residents and 85% of Utah’s children.25 Participating hospitals include a 289-bed freestanding tertiary care children’s hospital (PCH) located in a major metropolitan area, staffed by pediatric hospitalists and subspecialists, and both urban and rural general community hospitals with pediatric wards, staffed by general pediatricians and family physicians with limited pediatric resources.

PCH is affiliated with the Department of Pediatrics at the University of Utah and serves as a tertiary care pediatric referral hospital for Utah and 4 surrounding states (Wyoming, Nevada, Idaho, and Montana). The 7 Utah community hospitals were American Fork Community Hospital in American Fork, Dixie Regional Hospital in St George, Logan Community Hospital in Logan, McKay Dee Hospital in Ogden, Riverton Community Hospital in Riverton, Utah Valley Regional Medical Center in Provo, and Valley View Hospital in Cedar City. Overall, the 8 hospitals provide care to ∼700 asthmatic children each year and serve both urban (PCH, Riverton, McKay Dee, and Utah Valley) and rural (American Fork, Dixie, Valley View, and Logan) populations. The Intermountain Healthcare privacy and University of Utah institutional review boards approved the study.

Planning the Intervention

EB-CPM implementation at PCH was described previously.21 We disseminated the EB-CPM to 7 community hospitals by using the Replicating Effective Programs framework.26 We secured Intermountain Healthcare leadership support, which led to prioritization of our project as one of the organizational clinical goals, identified local hospital physician champions, and assembled a multidisciplinary implementation team with representatives from each hospital, including physician champions; nursing, respiratory therapy, and pharmacist leaders; hospital administrators; and QI staff. We obtained baseline compliance data for each hospital, which showed suboptimal asthma care, and shared these data with hospital clinical and administrative leaders. We secured local administrative leadership support, ensured buy-in of local clinical staff (physicians, nurses, respiratory therapists, and pharmacists) through education and training, and adapted the PCH training manual and decision support tools to fit local needs to facilitate EB-CPM integration into workflow.

The Intervention (Asthma EB-CPM)

Asthma EB-CPM Description

The EB-CPM was designed to standardize asthma care and support hospital compliance with EB asthma quality measures.8 The EB-CPM included decision support tools (admission and discharge order sets), with the following components: a standardized assessment of both acute and chronic asthma severity and control, recommendations for acute care and chronic asthma control, algorithms for escalating and weaning from albuterol and oxygen, criteria for specialist consultation, criteria for pediatric ICU transfer, criteria for discharge, and a standardized template and checklist to facilitate care transition to the primary care provider, including a written asthma action plan, patient and parent competency-oriented asthma education modeled on the Home Management Plan of Care,27 and algorithm-based stepwise adjustment of controller therapy.28

Implementation and Dissemination of the EB-CPM

We began EB-CPM implementation21 at PCH in January 2008 and completed it in March 2009 by using a Plan–Do–Study–Act rapid cycle approach.29,30 To ensure EB-CPM sustainability at PCH, we replaced the paper-based discharge order set with an electronic discharge process21,31 allowing automated information exchange and care continuity with primary care providers.20 The EB-CPM dissemination to community hospitals started in January 2011 and was completed in June 2011. We provided on-site education and training of clinical and administrative staff and...
data feedback during monthly meetings with participating hospital representatives. Feedback data were also shared with local hospital clinical and administrative staff by local physician champions. Finally, we provided ongoing technical assistance to physician champions and their teams for troubleshooting the implementation process.

Planning the Study
We used 8 EB quality measures from our previous work to evaluate the EB-CPM impact. These included 4 measures to assess compliance with EB treatments for acute exacerbations: (1) documented acute asthma severity on admission, (2) use of quick reliever medications in the hospital, (3) use of systemic corticosteroid medication in the hospital, and (4) restricted use of ipratropium bromide to <24 hours after admission. They also included 4 measures to assess compliance with EB measures intended to decrease readmission risk: (5) documented asthma education, (6) documented degree of chronic asthma control, (7) use of appropriate controller therapy prescription based on degree of asthma control, and (8) documented asthma action plan at discharge, with instructions on how to recognize and avoid triggers and with follow-up appointment date and time.

Data Collection
This was a QI study of children aged 2 to 17 years, discharged from participating hospitals between January 1, 2003, and December 31, 2013, with the International Classification of Diseases, Ninth Revision primary diagnostic code of asthma (493.xx). Data collection included compliance with the 8 quality measures and associated asthma outcomes and was completed manually for quality measures 1, 5, 6, 7, and 8, and electronically (using the Intermountain Healthcare enterprise data warehouse [EDW]) for quality measures 2, 3, and 4. Manual collection of compliance metrics was facilitated by creation of a Web-based data collection form, and data collection sources included physician and nursing documentation and medication administration records.

The EDW was used to collect outcome variables including asthma readmission (ED revisit or hospital readmission with a primary diagnosis of asthma) at any of 22 Intermountain hospitals, hospital LOS in hours, variable hospitalization cost (direct cost), hospital relative resource units (RRUs) used, ICU transfer within 24 hours of admission, and death. Hospitalization cost was inflation adjusted for 2013. RRU is a standardized value adjusted for inflation and local market factors to allow comparison of resource use between hospitals and across years, reflecting the relative intensity of resources used for each hospital charge. Finally, we used the EDW to retrieve demographic and other covariates, including age, gender, race, insurance, calendar month of hospitalization, and severity of illness (SOI) using All Patient Refined Diagnosis Related Groups.

For PCH, asthma discharges between January 2003 and March 2009 were defined as baseline (before implementation) with postimplementation discharges between April 2009 and December 2013. For community hospitals, asthma discharges between January 2003 and June 2011 were used as baseline, with postimplementation discharges including those between July 2011 and December 2013.

We included baseline data back to 2003 to take into account any preexisting secular trends. Baseline data were collected retrospectively and postimplementation data prospectively. For each patient, we recorded whether the care team was compliant with each measure (1 = yes and 0 = no). Individual measure compliance per patient was summed (ranging from 0 to 8) and used to calculate average compliance with individual measures and an average composite score per hospital.

Data Analysis
We compared patient characteristics between preimplementation and postimplementation periods using chi-squared for categorical and Wilcoxon t test for continuous variables. We assessed changes in compliance, by using the composite score, at PCH independently and at community hospitals as a group because of limited sample size at individual community hospitals. We used the “patient average” (cumulative percentage of quality measures achieved for each patient) method to calculate the composite score. We used statistical process control charts to visually assess changes over time in 6-month asthma readmission and LOS between the preimplementation and postimplementation periods. Log transformation was applied to LOS, cost, and RRU data, and log-linear regression analysis was used to compare these outcomes between preimplementation and postimplementation periods. These models were adjusted for covariates. Finally, we used Fisher’s exact test to assess the EB-CPM impact on PICU transfer.

RESULTS
There were 3510 children with asthma discharged from PCH and 1721 from community hospitals during the study period: 46.7% (1640/3510) and 74.3% (1279/1721) during preimplementation and 53.3% (1870/3510) and 25.7% (442/1721) during the postimplementation period, respectively. Table 1 compares demographic characteristics between preimplementation and postimplementation populations. At PCH, we noted significant differences...
in age, gender, race or ethnicity, insurance, and severity of illness (more severe after implementation). The community hospitals showed differences in race or ethnicity only, with similar severity of illness between implementation periods.

**Quality of Asthma Care**

Baseline compliance as measured by the composite score was low and highly variable across hospitals, with 45% at PCH and 25% to 58% at community hospitals (Fig 1). After implementation at PCH, average compliance with the composite score increased and was sustained at >90% for 5 years. Improvement of the composite score was rapid across the 7 community hospitals, reaching 80% to 99% within 6 months and remaining in this range over a 2-year follow-up period. Except for use of quick relievers and systemic corticosteroids, which had near optimal baseline compliance at all sites, increased compliance with individual quality measures followed different patterns at PCH (Supplemental Fig 4) and community hospitals (Supplemental Fig 5), with PCH showing progressive improvement with individual measures overall, whereas the improvement was rapid at community hospitals.

### TABLE 1 Patient Demographic Characteristics

<table>
<thead>
<tr>
<th>Characteristics Category</th>
<th>Before Implementation (January 2003–March 2009), n = 1640 (46.7%)</th>
<th>After Implementation (April 2009–December 2013), n = 1870 (53.3%)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Admit age, y, average (SD)</td>
<td>5.5 (3.5)</td>
<td>5.8 (3.5)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Gender, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>914 (55.7%)</td>
<td>1119 (59.8%)</td>
<td>.014</td>
</tr>
<tr>
<td>Female</td>
<td>726 (44.3%)</td>
<td>751 (40.2%)</td>
<td></td>
</tr>
<tr>
<td>Race or ethnicity, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>1178 (71.8%)</td>
<td>1250 (66.8%)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Hispanic</td>
<td>282 (17.2)</td>
<td>187 (10.0%)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>140 (8.5%)</td>
<td>397 (21.2%)</td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>40 (2.4%)</td>
<td>36 (1.9%)</td>
<td></td>
</tr>
<tr>
<td>Insurance, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medicaid</td>
<td>449 (27.4%)</td>
<td>635 (33.9%)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Private</td>
<td>1094 (66.7%)</td>
<td>1140 (60.9%)</td>
<td></td>
</tr>
<tr>
<td>Self-pay</td>
<td>97 (5.9%)</td>
<td>85 (5.1%)</td>
<td></td>
</tr>
<tr>
<td>Severity of illness, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1128 (68.8%)</td>
<td>1204 (64.4%)</td>
<td>.001</td>
</tr>
<tr>
<td>2</td>
<td>403 (24.8%)</td>
<td>466 (24.9%)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>94 (5.7%)</td>
<td>172 (9.2%)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>15 (0.9%)</td>
<td>28 (1.5%)</td>
<td></td>
</tr>
</tbody>
</table>

**Community Hospitals**

<table>
<thead>
<tr>
<th>Characteristics Category</th>
<th>Before Implementation (January 2003–June 2011), n = 1279 (74.3%)</th>
<th>After Implementation (July 2011–December 2013), n = 442 (25.7%)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Admit age, y, average (SD)</td>
<td>5.8 (3.7)</td>
<td>5.9 (3.7)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Gender, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>721 (60.6%)</td>
<td>307 (57.8%)</td>
<td>.279</td>
</tr>
<tr>
<td>Female</td>
<td>469 (39.4%)</td>
<td>224 (42.2%)</td>
<td></td>
</tr>
<tr>
<td>Race or ethnicity, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>1032 (80.7%)</td>
<td>333 (75.3%)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Hispanic</td>
<td>139 (10.9%)</td>
<td>4 (0.9%)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>88 (5.3%)</td>
<td>72 (4.2%)</td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>40 (3.1%)</td>
<td>33 (7.5%)</td>
<td></td>
</tr>
<tr>
<td>Insurance, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medicaid</td>
<td>332 (27.9%)</td>
<td>157 (29.6%)</td>
<td>.551</td>
</tr>
<tr>
<td>Private</td>
<td>809 (67.9%)</td>
<td>357 (67.2%)</td>
<td></td>
</tr>
<tr>
<td>Self-pay</td>
<td>49 (4.1%)</td>
<td>17 (3.2%)</td>
<td></td>
</tr>
<tr>
<td>Severity of illness, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>832 (69.9%)</td>
<td>387 (72.9%)</td>
<td>.260</td>
</tr>
<tr>
<td>2</td>
<td>328 (27.6%)</td>
<td>132 (24.9%)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>30 (2.5%)</td>
<td>11 (2.1%)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0 (0.0%)</td>
<td>1 (0.2%)</td>
<td></td>
</tr>
</tbody>
</table>

* Severity of illness: 1 = minor, 2 = moderate, 3 = major, and 4 = extreme.
Outcomes

The average asthma readmission rate at PCH significantly reduced after implementation when analyzed by regression analysis, and this reduction was sustained for 5 years after implementation (Fig 2). Average asthma readmission rate at community hospitals showed a small but not statistically significant reduction after implementation (Fig 3). Table 2 summarizes results of regression analyses comparing hospitalization outcomes (readmission, LOS, cost, and RRU) between the preimplementation and postimplementation periods and provides odds ratios (ORs) or $\beta$ coefficients ($\beta$) with 95% confidence intervals.

At PCH, we found a significant reduction in asthma readmission (OR 0.81; $P = .026$) and LOS ($\beta = -0.08; P < .001$) and a nonsignificant reduction in costs ($\beta = -0.04; P = .094$) (Table 2). Overall, improved asthma outcomes occurred without any increase in hospital resource use and no change in PICU transfer or death. At community hospitals, we found a nonsignificant trend toward reduced asthma readmission (OR 0.76; $P = .119$) and a significant reduction in LOS ($\beta = -0.24; P < .001$) and cost ($\beta = -0.05; P = .053$) (Table 2). Contrary to PCH, we observed a slight and significant increase in resource use at community hospitals ($\beta = 0.05; P = .032$) and, again, no change in PICU transfer or death. Supplemental Figs 6 and 7 show statistical process control charts depicting changes in LOS at PCH and community hospitals.

DISCUSSION

We demonstrated a high and sustained compliance with quality measures and a persisting reduction in asthma readmissions over 5 years at a tertiary care hospital after the EB-CPM implementation. We also found a significant reduction in LOS with a trend toward reduction in hospitalization costs. At community hospitals, our study showed successful EB-CPM dissemination, with improved compliance with quality measures and early evidence of improved asthma outcomes. We found a trend toward asthma readmission reduction and a significant reduction in LOS and hospitalization costs; however, improvements at community hospitals occurred with a slight increase in hospital resource use.

At both the tertiary care and community hospitals, baseline compliance with inpatient asthma quality measures targeting readmission prevention was generally low. This finding is consistent with previous studies reporting...
suboptimal care with regard to interventions targeting prevention of subsequent asthma hospitalizations.\textsuperscript{5,7,8,36–39} EB-CPM implementation resulted in improved care quality, including marked improvement in compliance with quality measures targeting asthma readmission prevention, across diverse inpatient settings.

We observed a significant and sustained reduction in asthma readmission at the tertiary care hospital but only a trend toward reduction in asthma readmission at community hospitals. It is likely that the small number of patients at the community hospitals did not provide sufficient statistical power to detect a significant reduction in readmission, and an extended postimplementation observation period will probably result in a significant change.

Finally, we found a slight increase in resource use at community hospitals, whereas resource use at PCH did not change. This finding highlights the fact that the demand to achieve and sustain high compliance with quality measures may require more hospital resource use. However, a reduction in hospital resource use may occur over time as community hospitals become familiar with the new process.

Several factors contributed to the success of our interventions, including administrative leadership support with prioritization of our project, QI culture within the Intermountain Healthcare organization, buy-in and support of local physician champions, use of an electronic discharge process, and the EB-CPM design itself, including asthma education and decision support tools integrated into the clinical workflow to facilitate compliance.\textsuperscript{40–42}

To our knowledge, this is the first study to report long-term compliance with EB inpatient asthma care measures and persisting positive impact on asthma outcomes after implementation of an EB-CPM. Our study is also unique in reporting successful dissemination of the intervention to diverse community hospital settings, with improved compliance with inpatient asthma care measures and outcomes.

Our study has several limitations. First, the tertiary care hospital (PCH) admitted most children (67%) with asthma, and the sample size at individual community hospitals was small. It was not possible to evaluate the EB-CPM effects at the individual hospitals.

![FIGURE 3](image)

**FIGURE 3**
6-Month asthma readmission rates: community hospitals. Slight but not significant reduction in 6-month asthma readmission rates after EB-CPM implementation. CL, central line; UCL, upper control limit.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Before Implementation</th>
<th>After Implementation</th>
<th>Odds Ratio or β</th>
<th>95% Confidence Interval</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-mo readmission rate, % (SD)</td>
<td>16.4 (37.0)</td>
<td>13.6 (34.3)</td>
<td>0.81*</td>
<td>0.67, 0.97</td>
<td>.026</td>
</tr>
<tr>
<td>LOS, h, median (IQR)</td>
<td>49 (35–77)</td>
<td>45 (33–69)</td>
<td>−0.08</td>
<td>−0.13, −0.04</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Hospitalization costs, adjusted for 2013 dollars, median (IQR)\textsuperscript{40}</td>
<td>1816.8 (1300.5–2614.2)</td>
<td>1705.6 (1144.9–2884.6)</td>
<td>−0.04</td>
<td>−0.08, 0.01</td>
<td>.094</td>
</tr>
<tr>
<td>RRU, median (IQR)</td>
<td>22.6 (16.4–33.6)</td>
<td>22.6 (15.5–39.3)</td>
<td>0.03</td>
<td>−0.02, 0.07</td>
<td>.218</td>
</tr>
</tbody>
</table>

Community Hospitals

<table>
<thead>
<tr>
<th>Variable</th>
<th>Before Implementation</th>
<th>After Implementation</th>
<th>Odds Ratio or β</th>
<th>95% Confidence Interval</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-mo readmission rate, % (SD)</td>
<td>13.8 (34.5)</td>
<td>11.5 (31.8)</td>
<td>0.76*</td>
<td>0.54, 1.07</td>
<td>.119</td>
</tr>
<tr>
<td>LOS, h, median (IQR)</td>
<td>44 (33–59)</td>
<td>35 (24–48)</td>
<td>−0.24</td>
<td>−0.29, −0.18</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Hospitalization costs, adjusted for 2013 dollars, median (IQR)\textsuperscript{40}</td>
<td>1556.9 (1157.4–2121.2)</td>
<td>1484.7 (1009.8–2066.3)</td>
<td>−0.05</td>
<td>−0.10, −0.001</td>
<td>.53</td>
</tr>
<tr>
<td>RRU, median (IQR)</td>
<td>22.3 (18.9–28.8)</td>
<td>22.9 (18.8–31.7)</td>
<td>0.05</td>
<td>0.00, 0.10</td>
<td>.032</td>
</tr>
</tbody>
</table>

Analysis was controlled for age, gender, race, insurance, severity, and month. IQR, interquartile ratio.

* Odds ratio.

\textsuperscript{40} Direct or variable costs related to inpatient asthma care.
community hospital level. Second, we used the EDW data to track asthma readmissions at any of the 22 Intermountain Healthcare hospitals. Although Intermountain Healthcare covers 85% of pediatric care in the state, we may have missed readmissions at non–Intermountain Healthcare facilities. The impact of this is unknown but unlikely to change our results. Third, implementation and dissemination received leadership support from Intermountain Healthcare and was facilitated by organizational changes at each facility to support compliance. The impact of leadership support and organizational change is difficult to estimate. Efforts to disseminate the EB-CPM to facilities outside Intermountain Healthcare may face additional challenges, although we believe that our approach to dissemination can be applied anywhere.

Fourth, our EB-CPM is complex. In our analysis we did not determine the individual effect of EB-CPM components on asthma outcomes. Fifth, the EB-CPM was introduced into a dynamic real-world clinical setting in which many other unmeasured variables may have affected the results, such as changes in access to asthma care, socioeconomic barriers to care, and improvements in the quality of asthma care resulting from introduction of the 2007 asthma guidelines. However, Fig 1 shows suboptimal compliance with quality measures at community hospitals that persisted ~4 years after the 2007 asthma guideline publication and changed only after EB-CPM implementation in 2011. We also believe that including insurance type, age, gender, race, underlying asthma severity, and calendar month in our adjusted analysis at least partially addressed unmeasured confounding factors. Sixth, we included SOI as a confounding factor in our regression analyses. SOI is an imperfect marker of illness severity at presentation. It is also a reflection of diagnoses coded and resource use.

Seventh, our study population included only children with a primary diagnosis of asthma, identified electronically through the EDW, and would exclude children with asthma discharged with another primary diagnosis, such as viral pneumonia. However, a review of our data suggested that including only those with a primary diagnosis of asthma captures the great majority of cases.

Lastly, previous studies have reported the effect of organizational factors on implementation of QI interventions and provider compliance with EB care. Specifically, success of an implementation strategy is a function of the relationship between the nature of the evidence, the context in which the proposed change is implemented, and the methods through which change is facilitated. Our future plan includes assessing organizational factors associated with successful implementation and dissemination of EB-CPMs. We hope to identify key factors that can be addressed to facilitate implementation and dissemination of an EB intervention to more broadly improve asthma care and outcomes.

**CONCLUSIONS**

Our results showed not only improved asthma care and outcomes but also long-term sustainability of the EB-CPM impact at PCH, a tertiary care children’s hospital, and successful dissemination to 7 community hospitals, with evidence of improvement in both the quality of asthma care and clinical outcomes. Our study demonstrates the potential use of EB-CPMs to achieve sustained improvement in asthma care and outcomes in various hospital settings.

**ACKNOWLEDGMENTS**

We acknowledge the medical, nursing, respiratory therapy, and administrative staff at participating hospitals for their efforts and diligence during the implementation and dissemination of the EB-CPM. We also thank the Pediatric Clinical Program leadership, including Dr Ed Clark and Ms Carolyn Reynolds, as well as Dr Brent James of the Intermountain Institute for Healthcare Delivery Research for their support for this project. Finally, Dr Nkoy has full access to all the data in the study and takes responsibility for the integrity of the data and accuracy of the data analysis.

**ABBREVIATIONS**

CS: composite score  
EB: evidence-based  
EB-CPM: evidence-based care process model  
ED: emergency department  
EDW: enterprise data warehouse  
LOS: length of stay  
OR: odds ratio  
PCH: Primary Children’s Hospital  
QI: quality improvement  
RRU: relative resource unit  
SOI: severity of illness  

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