Connecting At-Risk Inpatient Asthmatics to a Community-Based Program to Reduce Home Environmental Risks: Care System Redesign Using Quality Improvement Methods

INTRODUCTION: Connecting patients admitted with asthma to community-based services could improve care and more efficiently allocate resources. We sought to develop and evaluate an intervention to mitigate in-home environmental hazards (eg, pests, mold) for such children.

METHODS: This was a controlled, quality improvement study on the inpatient units of an urban, academic children's hospital. Clinicians and public health officials co-developed processes to identify children with in-home risks and refer them for assessment and remediation. Processes assessed were the rate at which those identified as eligible were offered referrals, those referred received inspections, and primary care physicians (PCPs) were notified of risks and referrals. Consecutively occurring and seasonally matched intervention ($n = 30$) and historical control ($n = 38$) subcohorts were compared with respect to postdischarge mitigating actions (eg, discussions with landlords, PCPs), remaining risks, and morbidity (symptom-free days in previous 2 weeks and Child Asthma Control Test scores).

RESULTS: In the first year, the percentage of eligible children offered referrals increased to a sustained rate of $\sim 90\%$; $\sim 65\%$ of referrals led to in-home inspections ($n = 50$); and hazards were abated in 30 homes. PCP notification increased from 50% to $\sim 80\%$. After discharge, referred parents were more likely to discuss concerns with landlords, the health department, attorneys, and PCPs than patients admitted preimplementation (all $P < .05$). Referred households were more likely to report reduced presence of $\geq 2$ exposures ($P < .05$). No differences in asthma morbidity were observed.

CONCLUSIONS: We integrated environmental hazard mitigation into inpatient care. Community-engaged care delivery that reduces risks for poor asthma outcomes can be initiated within the hospital.

INTRODUCTION

Home environmental exposures affect childhood asthma.$^1$–$^6$ More than 50% of high-risk inner-city children with moderate to severe asthma report exposure to cockroaches and 45% report exposure to mold; these exposures have been linked to poor asthma outcomes.$^7$–$^8$ For example, compared with those not exposed or sensitized to cockroaches, those both exposed and...
sensitized have 1 additional symptom-day per 2-week period and 3 additional unscheduled visits per 1000 person-days. Still, despite the presumed impact of in-home environmental hazards on postdischarge morbidity, potentially remediable exposures often go undetected during the inpatient stay.

Community-based interventions that promote healthy housing have been shown to improve asthma-related quality of life. A systematic review of programs, including environmental assessment, education, and remediation, suggests that such interventions reduce symptom-days by 21, missed school-days by 12, and acute asthma visits by 0.6 per year. Boston’s Breathe Easy at Home program facilitates referrals from pediatric primary care practices to public health and housing agencies poised to provide assessment, education, and code enforcement if home environmental hazards are identified. An analogous inpatient intervention that makes use of preexisting community resources could play an important role in reducing in-home exposures and, potentially, postdischarge morbidity.

Historically, asthma-related housing risks were not routinely addressed during inpatient stays at our institution, perhaps because there was little help inpatient providers felt they had to offer. Therefore, with the Boston collaborative as a guide, the current article describes a quality improvement (QI) initiative focused on identifying and responding to in-home exposures on the inpatient asthma unit. Partnerships between inpatient care and community-based services that address in-home hazards have the potential to improve care as children transition home and to simultaneously allocate resources more efficiently and effectively.

**METHODS**

**Study Design**

This controlled, QI study had 3 phases. First, we developed and refined processes to refer patients with identified home environmental risks to an existing health department program. Second, once the referral process was reliably implemented, we compared an intervention subcohort of consecutively admitted patients with a seasonally matched subcohort of patients who had been enrolled in a prospective, observational study the year before. Subcohorts were compared with respect to remaining exposures, actions initiated after discharge to mitigate in-home risks (eg, discussions with landlords, health department inspectors, attorneys, primary care physicians [PCPs]) and subsequent asthma morbidity. Finally, we developed and refined processes aimed at informing PCPs at discharge about the risks identified and referrals initiated during the admission. This study was determined to be exempt by the Cincinnati Children’s Hospital Medical Center (CCHMC) institutional review board.

**Setting**

Cincinnati, Ohio, has a population of ~60,000 children (aged 1–16 years) and an asthma admission rate twice the national average. Much of Cincinnati is marked by old, poor-quality housing, with the median housing unit built in 1949. Upon request, Cincinnati Health Department (CHD) sanitarians (inspectors) assess homes for health and safety hazards guided by local Board of Health regulations. If hazards are noted, inspectors provide education to tenants and landlords and write orders for remediation if indicated. With limited resources, CHD is interested in targeting inspections to those most likely to benefit.

CCHMC is a 425-bed, urban, academic children’s hospital. Approximately 1250 children are admitted annually for asthma or wheezing; many of these children live in impoverished neighborhoods with substandard housing. In 2008, CCHMC began a strategic drive to improve outcomes for patients with asthma, focusing initially on hospitalized patients. In September 2010, CCHMC published an updated “Evidence-Based Care Guideline for Management of an Acute Asthma Exacerbation,” which included new recommendations to address socioeconomic outcome disparities. At the time of the guideline’s publication, routine home environmental screening was documented in the charts of admitted asthmatic patients 2% of the time. Those with risks identified were most commonly referred to social services, but there were no standard processes in place to connect patients with community resources such as those provided by CHD.

**Planning the Intervention**

CCHMC inpatient physicians approached CHD Environmental Health Services officials to develop an intervention for children with identified in-home environmental risks. The resulting partnership, established with the support of a local Community-Academic Partnership Grant, was called Collaboration to Lessen Environmental Asthma Risks (CLEAR).

CLEAR required the development, refinement, and integration of processes that were initially separate or nonexistent (Fig 1). New hospital-based processes included consistent assessments of environmental exposures,
evaluation of CLEAR implementation, we actively tracked children, aged 1 to 16 years, admitted for asthma or bronchodilator-responsive wheezing. Children were identified according to admission diagnosis and physician use of the evidence-based asthma order set for the standardized bronchodilator-weaning protocol. The identification of eligible patients (those meeting inclusion criteria and reporting an environmental risk) was assessed through use of the asthma-specific H&P.24 We then assessed the consistency with which CLEAR was offered to those identified as eligible, the frequency with which referrals led to inspections, and the frequency with which referrals were documented in discharge summaries. The denominator for assessed process measures was changed in August 2011 to include children living in areas under the jurisdiction of either CHD or HCPH. Despite broadened eligibility beyond the city of Cincinnati, CLEAR’s impact was quantified by the number of referrals made, visits completed, orders written, and orders abated within city limits during the first year. Abatement was defined as hazard remediation that met Cincinnati Board of Health standards. Consecutively occurring and seasonally matched intervention and historical control subcohorts were compared to further strengthen program evaluation. The intervention subcohort included Cincinnati residents referred to CLEAR between January and June 2012 (n = 40). January to June was chosen a priori to allow for process refinement during CLEAR’s first 6 months. The...
historical control subcohort included children admitted between January and June 2011 (to limit the effect of season on analysis) who lived within Cincinnati and had home environmental exposures identified before implementation of CLEAR (n = 53). Exposures were identified during a face-to-face survey completed as part of a separate observational cohort study that included questions identical to those ultimately included in the asthma-specific H&P.24 Demographic covariates for both subcohorts were obtained from the EHR. A telephone survey, completed for both subcohorts 45 to 90 days after discharge, assessed respondent-reported action steps, including discussions with landlords, sanitarians, attorneys, and PCPs; progress toward risk reduction; and continued hazard presence. Postdischarge morbidity was assessed through reported symptom-free days in the 2 weeks preceding the call and scores on the Childhood Asthma Control Test (C-ACT), a validated assessment of symptoms, functioning, and quality of life.26 The C-ACT is scored on a continuous scale. Scores above 19 indicate good control; scores below 19 indicate poor control.

Analysis

Implementation phase processes were analyzed by using annotated Shewhart charts with special cause determined by using established rules.27 Descriptive statistics enumerated referral outcomes over the 1-year period.

Intervention and control subcohorts were compared by using χ² tests for categorical variables and Wilcoxon rank sum tests or t tests for continuous demographic characteristics, postdischarge action steps, and measures of asthma morbidity. Each exposure, and the total number of exposures, was defined as better, worse, or the same at follow-up; thus, change could be bidirectional. It was then possible to compare change in exposures between groups by using the Wilcoxon rank sum test.

RESULTS

Between July 2011 and June 2012, a total of 562 children, aged 1 to 16 years, from the city of Cincinnati were admitted to CCHMC for asthma or wheezing. The mean ± SD age was 6.1 ± 4.0 years, and 61% were male. A total of 84% were African American and 11% were white; 88% were publicly insured and <3% were uninsured. Eighteen percent (n = 99) had at least 1 environmental risk identified on the H&P.

Among those with a reported risk, the rate at which CHD referrals were offered reached a sustained rate of nearly 90% (Fig 2). This increase was aided by the new H&P,24 EHR-based decision supports, education, data sharing, and identification and mitigation of process failures. If a CLEAR-eligible patient did not receive a referral and no reason was documented in the EHR, study personnel contacted the appropriate resident or attending. If a referral was intended, study personnel helped the clinician complete the submission process successfully. If the referral was not intended, study personnel sought qualitative feedback to inform ongoing improvement. Among patients referred, the mean rate at which home inspection occurred was ~65%, varying from month-to-month (Supplemental Fig 3A). The rate at which information was transmitted to the PCP reached nearly 80%, an increase driven primarily by EHR-based phrases inserted into discharge summaries (Supplemental Fig 3B).
Among 99 eligible patients, 75 accepted referrals during the inpatient stay. Of the 24 who declined, 3 reported the issue was already being addressed and 2 had plans to move; 19 had no documented reason for refusal. The 75 referrals resulted in 50 inspections; reasons for nonvisits including inability to reach the family (n = 15) or a family that had changed their mind (n = 8). All inspections included complaint-focused environmental assessments; after October, all visits also included the more complete Healthy Homes education and assessment protocol. Thirty visits involved code enforcement orders, which all resulted in risk abatement.

### Postdischarge Intervention-Control Comparison

Forty intervention households were compared with 53 control households; 75% of the intervention (n = 30) and 72% of the control (n = 38) households completed the telephone survey. Groups did not differ with respect to the time between hospital discharge and survey completion (Table 1). However, intervention patients were more likely to be African American and report cockroaches and mold/mildew in the home; control subjects were more likely to report water damage and cracks/holes in the walls or ceiling. There were no within-group differences between those completing and not completing the survey.

The intervention subcohort was significantly more likely to have had environmental exposures addressed during the hospitalization (P < .0001) (Table 2). They were also significantly more likely to have postdischarge discussions with their landlord, sanitarians, an attorney, and/or their PCP (all: P < .05).

Compared with exposures reported on admission, intervention households reported significantly greater reductions in cockroach (53% to 27%), mold/mildew (70% to 17%), and presence of ≥2 exposures (63% to 10%) than those reported by control subjects (all: P < .05) (Table 3). No significant differences were noted between groups for changes in exposures to rodents, water damage, or cracks/holes. There were also no differences in symptom-free days in the previous 2 weeks (10.9 vs 10.4 days; P = .07) or C-ACT scores (18.0 vs 20.1; P = .2).

### DISCUSSION

Through community collaboration, we systematically identified and addressed asthma-related home environmental exposures during inpatient care. In CLEAR’s first year, 75 hospitalized children were connected to a community resource aimed at upholding healthy housing conditions. Those referred were more likely to report hazard reduction than children admitted before implementation of CLEAR. To our knowledge, this intervention is the first such program involving community collaboration and utilization of a preexisting community resource to be initiated among children admitted with asthma, a population at especially high clinical and social risk.

### TABLE 1 Demographic Characteristics of the Seasonally Matched Control (2011) and Intervention (2012) Subcohorts

<table>
<thead>
<tr>
<th>Patient Characteristic</th>
<th>2011 (n = 38)</th>
<th>2012 (n = 30)</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean ± SD, y</td>
<td>72 ± 4.1</td>
<td>6.0 ± 4.3</td>
<td>.2</td>
</tr>
<tr>
<td>Race, %</td>
<td></td>
<td></td>
<td>.005</td>
</tr>
<tr>
<td>African American</td>
<td>71</td>
<td>93</td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>29</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Male gender, %</td>
<td>71</td>
<td>63</td>
<td>.5</td>
</tr>
<tr>
<td>Public insurance, %</td>
<td>97</td>
<td>97</td>
<td>.9</td>
</tr>
<tr>
<td>Risk present on admission, %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cockroaches</td>
<td>26</td>
<td>53</td>
<td>.02</td>
</tr>
<tr>
<td>Rodents</td>
<td>13</td>
<td>10</td>
<td>.7</td>
</tr>
<tr>
<td>Mold/mildew</td>
<td>38</td>
<td>70</td>
<td>.009</td>
</tr>
<tr>
<td>Water damage</td>
<td>68</td>
<td>43</td>
<td>.04</td>
</tr>
<tr>
<td>Cracks/holes in the walls or ceilings</td>
<td>71</td>
<td>17</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>≥2 exposures, %</td>
<td>66</td>
<td>63</td>
<td>.8</td>
</tr>
<tr>
<td>Days from discharge to survey completion, mean ± SD</td>
<td>74 ± 18</td>
<td>63 ± 21</td>
<td>.4</td>
</tr>
</tbody>
</table>

Historical controls included consecutive children admitted between January and June 2011 with environmental exposures identified before CLEAR implementation during a face-to-face research study. The intervention subcohort included those referred to CLEAR between January and June 2012.

* Wilcoxon rank sum test or t test for continuous variables, \( \chi^2 \) test for categorical variables.

### TABLE 2 Action Steps Taken During and 45 to 90 Days After Admission for the Seasonally Matched Control (2011) and Intervention (2012) Subcohorts

<table>
<thead>
<tr>
<th>Action Steps</th>
<th>2011 (n = 38)</th>
<th>2012 (n = 30)</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental risks addressed during hospital stay</td>
<td>26</td>
<td>100</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Housing concerns discussed between admission and follow-up call with</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landlord</td>
<td>67</td>
<td>87</td>
<td>.03</td>
</tr>
<tr>
<td>Health Department inspector</td>
<td>17</td>
<td>90</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Attorney</td>
<td>6</td>
<td>10</td>
<td>.03</td>
</tr>
<tr>
<td>Child’s pediatrician or nurse</td>
<td>25</td>
<td>33</td>
<td>.03</td>
</tr>
<tr>
<td>Discussions reported to be helpfulb</td>
<td>36</td>
<td>77</td>
<td>.0006</td>
</tr>
</tbody>
</table>

Data are presented as %. Historical controls included consecutive children admitted between January and June 2011 with environmental exposures identified before CLEAR implementation during a face-to-face research study. The intervention subcohort included those referred to CLEAR between January and June 2012.

* \( \chi^2 \) test.

** Includes those reporting ≥1 of the housing concern discussions: 2011 (n = 25) and 2012 (n = 27).
Given that children with chronic conditions, including asthma, now account for a majority of hospital discharges,\textsuperscript{28} inpatient care and discharge models that reliably target clinical and social risks are critical.\textsuperscript{29–31} Although primary care–community collaboration has grown,\textsuperscript{32–34} inpatient–community collaboration is uncommon but could help target such risks and, potentially, reduce morbidity. For CLEAR, housing inspectors were seen as collaborative consultants who could answer questions and intervene in areas in which clinicians had limited knowledge and access to interventions.\textsuperscript{3,35} Just as physicians consult clinical specialists to answer clinical questions, we consulted housing specialists to address a critical social determinant of health.

Hospital–health department connections were facilitated by changes made to preexisting processes, especially when engineered into the EHR. Process sustainability was aided by ongoing education, data sharing, and identification and mitigation of failures, similar to reports of clinic-based QI programs and our own implementation of the H&P.\textsuperscript{24,36–39} EHR-based processes also facilitated connections between hospitals and PCPs. Such connections, particularly the linking of a hospital with community resources, may represent a broader opportunity to explore “meaningful use” of EHRs.

However, many families did not accept the intervention and, when accepted, many inspections were not completed. We expect some families were worried about referral repercussions (eg, illegal landlord retribution). The brochure was created in an attempt to limit this worry, and it provided contact information for local legal advocates. Negative past experiences with public agencies may also have influenced a family’s decision to refuse a referral.\textsuperscript{40} For those who did accept a referral, visits were not always completed, reflecting similar challenges faced by clinical subspecialists and families lost to follow-up. For example, 39% of children referred to mental health providers were never seen.\textsuperscript{41} Thus, more work is needed to understand and resolve barriers to both referral acceptance and follow-through.

Despite such barriers, reduction of cockroach, mold/mildew, and ≥2 exposures (conceptualized as relevant to the Healthy Homes approach) occurred to a significantly greater extent for those referred to CLEAR compared with control subjects. Given that control subjects also saw decreases in exposures to rodents, water damage, and cracks without documented inpatient-initiated interventions, it is possible that some households took action despite inaction by clinical providers during admissions. It is also possible that the observed benefit of CLEAR may have been driven, in part, by postdischarge discussions of in-home exposures, with clinical and community agencies poised to intervene. Limited control over environmental trigger avoidance is a barrier to optimal asthma care faced by urban families.\textsuperscript{3} Families with such competing priorities have poorer chronic control and lower rates of medication adherence.\textsuperscript{5} Another possible benefit of CLEAR may be the re-establishment of some “control” over a family’s home environment.\textsuperscript{42}

Balancing cost and benefit is increasingly relevant in the current health economic climate. Although home environmental interventions have consistently been shown to improve health outcomes,\textsuperscript{11,16–18,43,44} we saw no significant differences in symptom-free days or C-ACT scores at follow-up. It is possible that 45 to 90 days is not an adequate follow-up period or that our sample size was insufficient to assess this outcome. It is also possible that different demographic and risk profiles between the intervention and control groups complicated direct comparisons. For example, cockroaches or mold may have a greater impact on asthma morbidity than the other risks; hence, the intervention subcohort may have been sicker at baseline. Other exposures (eg, pets, dust, tobacco) could have also masked the effect of beneficial modifications. Further work that more directly analyzes the

### TABLE 3 Environmental Risk Change Between Time of Admission Assessment and Follow-up 45 to 90 Days After Admission for the Seasonally Matched Control (2011) and Intervention (2012) Subcohorts

<table>
<thead>
<tr>
<th>Risk Presence</th>
<th>Risk Presence</th>
<th>$P^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in 2011</td>
<td>in 2012</td>
</tr>
<tr>
<td></td>
<td>Sample ($n = 38$)</td>
<td>Sample ($n = 30$)</td>
</tr>
<tr>
<td>Baseline (%)</td>
<td>Follow-up (%)</td>
<td>Baseline (%)</td>
</tr>
<tr>
<td>---------------</td>
<td>----------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Cockroaches</td>
<td>26</td>
<td>29</td>
</tr>
<tr>
<td>Rodents</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>Mold/mildew</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>Water damage</td>
<td>68</td>
<td>18</td>
</tr>
<tr>
<td>Cracks/holes</td>
<td>75</td>
<td>55</td>
</tr>
<tr>
<td>≥1 exposures present</td>
<td>100</td>
<td>68</td>
</tr>
<tr>
<td>≥2 exposures present</td>
<td>66</td>
<td>45</td>
</tr>
</tbody>
</table>

Historical controls included consecutive children admitted between January and June 2011 with environmental exposures identified before CLEAR implementation during a face-to-face research study. The intervention subcohort included those referred to CLEAR between January and June 2012. A Wilcoxon rank sum test comparing the intervention (2012) and control (2011) subcohorts with respect to change in risk presence from time of admission to time of follow-up.
potential clinical effectiveness and cost-effectiveness of CLEAR would be warranted, taking into account its utilization of preexisting infrastructure. Such an analysis could also compare the nature of hospital-initiated complaints versus complaints initiated by the general population to see if CLEAR more efficiently targeted public resources.

Study Limitations

The study did have some limitations. Given that this was a local intervention, its generalizability may be limited. Still, collaborative interventions initiated on the inpatient unit could be pursued in analogous ways in other communities. As an example, by extending CLEAR to areas in HCPH’s jurisdiction in August 2011, an additional 26 referrals and 17 inspections were completed through June 2012. We expect the use of preexisting community resources will also enhance CLEAR’s long-term sustainability and further spread potential. Second, because not every eligible household agreed to a referral, effect estimates may be subject to selection bias (ie, those accepting referrals may have been more ready to act). Relatedly, given that the rate of environmental risk detection (18%) was likely an underestimation of true risk presence, those reporting a risk may have been more ready to act and less affected by social desirability bias. Finally, these data cannot prove that CLEAR directly led to observed changes. Although randomization or a concurrent, matched control group may have more convincingly assessed CLEAR’s impact, these methods were beyond the scope of the project and limited by CCHMC’s steadily evolving inpatient asthma care setting. Furthermore, the strong support in the literature regarding the effect of environmental hazard mitigation on asthma outcomes reinforces our current focus on the process of connecting families to such services.

Future Directions

We plan to continue to follow up with children referred to identify whether morbidity is affected over a longer period of time and to explore why certain families decline in-home inspections. In addition, we are reaching out to primary care clinics, the emergency department, and other health departments as potential areas of spread. We also plan to seek out other partnerships targeting additional risks (eg, caregiver mental health) that would complement the current focus on housing.

CONCLUSIONS

The current project built on a nascent relationship between a hospital and public health agency, using the expertise of both organizations to connect the right patients to the right resource. We expect that further efforts toward community engagement and partnership may help the inpatient setting initiate chronic asthma risk management alongside treatment of the acute exacerbation.

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