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Boston children's hospital community asthma initiative: Five-year cost analyses of a home visiting program

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ABSTRACT

Objective: To evaluate the costs and benefits of the Boston Children's Hospital Community Asthma Initiative (CAI) through reduction of Emergency Department (ED) visits and hospitalizations for the full pilot-phase program participants. **Methods:** A cost-benefit analyses was conducted using hospital administrative data to determine an adjusted Return on Investment (ROI): on all 268 patients enrolled in the CAI program during the 33-month pilot program phase of CAI intervention between October 1, 2005 and June 30, 2008 using a comparison group of 818 patients from a similar cohort in neighboring ZIP codes without CAI intervention. Cost data through June 30, 2013 were used to examine cost changes and calculate an adjusted ROI over a 5-year post-intervention period. **Results:** CAI patients had a cost reduction greater than the comparison group of \$1,216 in Year 1 ($P = 0.001$), \$1,320 in Year 2 ($P < 0.001$), \$1,132 ($P = 0.002$) in Year 3, \$1,123 ($P = 0.004$) in Year 4, and \$997 ($P = 0.022$) in Year 5. Adjusting for the cost savings for the comparison group, the cost savings from the intervention resulted in an adjusted ROI of 1.91 over 5 years. **Conclusions:** Community-based, multidisciplinary, coordinated disease management programs can decrease the incidence of costly hospitalizations and ED visits from asthma. An ROI of greater than one, as found in this cost analysis, supports the business case for the provision of community-based asthma services as part of patient-centered medical homes and Accountable Care Organizations.

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Introduction

Pediatric asthma, one of the most common chronic illnesses among children in the United States, has reached historically high rates (9.5% for children under 18 years) with large racial and ethnic disparities [1,2]. Nationally, asthma is the fourth-ranking cause of hospitalization among children [3–5]. In Massachusetts, an estimated 168,163 (8.4%) children suffer from asthma [6]. A study under Pediatric Asthma Surveillance Program for schools conducted by the Massachusetts Department of Public Health during 2005–2008 revealed a 10.6% to 10.9% prevalence of asthma statewide among school children, with Boston schools reporting a significantly higher prevalence of 13.9% [7].

Asthma is the leading cause of hospitalization at Boston Children's Hospital (Boston Children's) where 70% of children hospitalized for asthma come from predominantly African American and Latino, low-income neighborhoods adjacent to the hospital. Among these neighborhoods, according to the Pediatric Asthma

Surveillance in Massachusetts between 2005 and 2009, the rate of asthma prevalence for children in Kindergarten through grade 8 from Roxbury was the highest, while North and South Dorchester had the third- and fourth-highest rates of asthma in Boston [7]. The asthma hospitalization rate for children under the age of five in Boston was higher for Black (14.3 per 1000) and Latino (9.9 per 1000) children than for White children (2.8 per 1000) [8].

When accounting for the range of factors contributing to overall health, previous authors have calculated that medical care contributes only 10–15% to the health of populations with 30% to genetics, 60% to physical environment, social factors and individual behavior [9]. These social determinants often have a negative impact on health, when individuals and families are living in poverty: Substandard housing due to poverty and/or racial bias in housing policy is a significant source of asthma triggers, and people living in high-poverty neighborhoods are more likely to be exposed to stressful

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conditions, such as unemployment, community violence and failing schools [10]. Parents often lack the health literacy, resources or support to understand or adhere to asthma controller medications or eliminate home environmental triggers. Home visiting programs which utilize Community Health Workers, such as CAI, provide additional education, resources and support in a setting where parents and youth feel less rushed and more comfortable to review medications, ask questions, discuss health beliefs, as well as financial and social barriers to asthma control and receive remediation of home environmental triggers [11].

To be cost-effective, interventions like the Community Asthma Initiative (CAI) must be targeted to children with higher asthma severity or higher social and environmental needs [12]. Enrollment criteria for CAI patients include: 1) patients with a hospital admission or Emergency Department (ED) visit in the previous 12 months, 2) a prescription for oral corticosteroids in the last 12 months or 3) referrals from specialty and primary care providers. Most patients come from neighborhoods where poverty is high and housing conditions are poor. The CAI provides nurse and/or Community Health Workers (CHWs) home visits with tailored asthma education, case management, education about medication adherence, and home environmental assessments and remediation [13].

A number of previous studies demonstrate that community-based case management and home visits can have a significant impact on lowering morbidity among children with asthma [14–24]. However, most of these studies focus only on the health benefits arising from such intervention rather than conducting a cost-benefit analysis of comprehensive programs. In addition, most studies do not use comparison groups to control for other factors that may account for some of the benefits. Two recent studies have presented a cost-benefit analysis using a comparison group but with only one year of follow-up data [25, 26].

In 2012, the health outcomes and cost analysis for FY2006 CAI patients ($N = 102$) served during the first full year of the program were published. Based on the cost savings over 2 years after intervention an unadjusted ROI of 1.46 was calculated from the intervention [27]. A subsequent adjusted cost analysis of the FY2006 CAI patients after subtracting cost savings in a comparison group with 3 years of follow-up data was published in 2013 and reported an adjusted ROI of 1.33 at 3 years after intervention [28].

Our objective for our research was to extend previous cost analyses, which were only for patients served in CY2006, to all patients recruited during the 33 months of the pilot phase of the CAI program from October 1,

2005 to June 30, 2008 ($N = 268$). This will be compared to the full-comparison group from the same time period and adjacent ZIP codes ($N = 818$). An adjusted ROI will be computed based on the higher cost reduction for the intervention than the full-comparison group over 5 years after enrollment/index date using data through June 30, 2013. The CAI patients will also be compared with a high-cost subgroup, a subset of the full-comparison group of patients, who had similar levels of asthma severity as the intervention group at intake. The present analysis thus extends the time frame from a 2-year to 5-year follow-up period and also adds a comparison as well as a high cost comparison group.

Methods

Study subjects

The intervention group consisted of 268 children enrolled in the CAI program who were hospitalized at Boston Children's due to asthma, or had asthma-related ED visits between October 1, 2005 and June 30, 2008. Intervention patients were identified from administrative lists of ED visits and hospitalizations at Boston Children's. The intervention group participants were initially seen or contacted by nurse case managers with subsequent nurse and/or CHW home visits and case management with follow-up phone calls for 1 year. Previous GIS mapping have demonstrated that majority of CAI patients lived in a poverty area ($\geq 20\%$ of the population lives below the federal poverty level) and lived in areas that are predominantly Black or Hispanic [13].

The full-comparison group consisted of 818 children ages 2–18 years from 4 neighboring ZIP codes with similar demographic characteristics as the CAI patients (areas that are predominantly Black or Hispanic with $\geq 20\%$ population living below federal poverty levels), but who did not receive CAI services. The full-comparison group was selected based on similar criteria used for recruiting CAI patients, and consisted of children with two or more ED visits or hospitalizations at Boston Children's due to asthma between October 1, 2005 and September 30, 2006 and between October 1, 2007 and June 30, 2008. The 1-year gap was chosen to avoid overlap between one year back analyses and new patient selection. Since the full-comparison group did not have an enrollment date, their first ED visit or hospitalization at Boston Children's during the study period was chosen as their index date.

The severity and costs among the full-comparison group patients were lower on average than those among CAI patients. The baseline year per patient cost among the full-comparison group was about 30% lower than that for the CAI group, as some of the full-comparison group

had fewer hospitalizations or ED visits in the baseline year. CAI patients are clinically triaged using disease severity, number of exacerbations and medications needed for control of symptoms.

Nurses identified the patients most in need of services. Most patients served were hospitalized or have two or more ED visits, and are higher cost than the full-comparison group patients. To complete a sensitivity analysis, a separate high-cost subgroup of the full-comparison group with baseline costs in the same range as the CAI patients was tracked to analyze differences in the trend in costs. The similar severity high-cost subgroup analysis included 230 patients who did not receive CAI intervention and had at least one hospitalization or 2 ED visits 1 year before inclusion in the study.

Study variables and outcomes

For the cost analysis, costs incurred through ED visits and hospitalizations were used to determine health care cost changes. For the intervention, full-comparison group, and high-cost subgroup, cost savings were computed as the difference in costs for ED visits and hospitalizations 1 year before the enrollment/index date, and 5 years of follow-up. The average annual clinical program cost incurred for patients enrolled in the intervention program during the study period was used as the cost of intervention. Staff costs and cost of supplies (vacuums, bedding encasement, integrated pest management materials, etc.) were the main components of the program costs.

Two parameters, Net Present Value (NPV) and Return on Investment (ROI) were used to quantify the net benefits resulting from CAI services [29, 30]. An adjusted ROI was used to examine whether the investments made under CAI resulted in benefits that exceeded the investment cost and to determine the extent of the total return on investment from the CAI intervention over time [31].

$$\begin{aligned} \text{NPV} &= \text{Present Value of Cost Savings} \\ &\quad - \text{Present Value of Program Costs} \\ \text{ROI} &= \text{Present Value of Cost Savings} / \\ &\quad \text{Present Value of Program Costs} \end{aligned}$$

Because the costs and benefits included in the analysis accrued over a prolonged time period, the values were made comparable by converting all future monthly values into their present value at the beginning of the study period. To compute the net benefits an annual discount rate of 10% was selected from the high end of a range of discount rates generally used in health and social sector projects to determine the present values [32–34]. The higher rate of 10% is selected to account for the higher

inflation in the health sector compared to the overall inflation in the economy, and a positive return with such a conservative estimate would ensure that positive returns will be even higher using a lower discounting rate. As the intervention and the comparison groups were studied during similar time periods, and inflation if any was small during the period, no adjustments were made for inflation.

The NPV and ROI were based on total costs including hospitalization and ED visit costs from hospital administrative data for patients. The program cost incurred for CAI patients was used as the cost of services. An adjusted ROI was calculated after subtracting the cost savings among the full-comparison group from the cost savings from the CAI intervention group using a multivariable regression controlling for demographic variables. This adjustment helped remove any reduction in costs attributable to factors other than CAI intervention.

Data collection

Cost data for the intervention and comparison groups were obtained from Boston Children's Hospital's administrative data. The hospital cost calculations included expenses incurred by patient care departments such as labor and supplies, as well as overhead costs such as depreciation and building costs; however, this neither included physician costs submitted through provider foundations nor pharmacy costs. The Boston Children's Institutional Review Board's approval was obtained for this quality improvement initiative to access hospital administrative data and case management data for evaluation.

Statistical analysis

Demographic data among the intervention and comparison groups were compared using Chi-Square test for categorical variables and unpaired *t*-test for continuous variables. Paired *t*-tests were used to compare costs for within group comparisons one year before intervention/index date and 5 years after. Unpaired *t*-tests were used to compare changes in cost savings for between group comparisons through 5 years after intervention. To account for issues caused by non-normality of the data, non-parametric counterpart of both unpaired and paired *t*-tests were performed if data contained small cells. After accounting for cost savings for the full-comparison group five years after intervention, adjusted cost reduction per patient was determined for the intervention group using a multivariable regression analysis that controlled for gender, age, race/ethnicity and insurance type.

The Cohen's *d* was 0.4. With a significance level of 0.05, the power to detect cost changes caused by CAI

Table 1. Demographics for CAI pilot phase and full comparison group patients.

	I. Community Asthma Initiative (N = 268*)	II. Full Comparison (N = 818*)	P-value CAI and Full Comparison (I vs II)	III. High Cost Subgroup (N = 230*)	P-value CAI and High Cost Subgroup (I vs III)
Age, mean in years (SD)	6.9 (4.1)	6.1 (3.9)	0.34	6.4 (5.2)	0.56
Gender					
Male	150 (56%)	468 (57%)	0.72	139 (60%)	0.31
Female	118 (44%)	350 (43%)		91 (40%)	
Insurance:					
Medicaid/MassHealth	195 (73%)	556 (68%)	0.14	155 (67%)	0.19
Private	73 (27%)	262 (32%)		75 (33%)	
Race/Ethnicity:					
Hispanic	122 (46%)	326 (41%)	0.22	87 (39%)	0.28
Non-Hispanic Black	110 (42%)	382 (48%)		107 (49%)	
Other	31 (12%)	91 (11%)		27 (12%)	

*Percentages do not include missing data.

intervention was 93%. The statistical analyses were completed using SPSS 19.0 software and were 2-tailed.

Results

Intervention and full-comparison groups cost differences

There were no differences in age, gender, race/ethnicity, and insurance type between the CAI group, the full-comparison group, and the high-cost subgroup (Table 1). Cost per patient analyses demonstrated a large reduction in cost between pre-intervention and each of the 5 years post-intervention for the intervention group (Table 2). In contrast, the cost reduction per patient among the full-comparison group between pre-index and each of the 5 years' post-index date was less (Table 2). CAI patients had a cost reduction greater than the full-comparison group of \$1,216 in Year 1 ($P = 0.001$), \$1,320 in Year 2 ($P < 0.001$), \$1,132 ($P = 0.002$) in Year 3, \$1,123 ($P = 0.004$)

in Year 4, and \$997 ($P = 0.022$) in Year 5 (Table 2). The percentage reduction in costs 5 years' post-intervention was higher among CAI patients than among the full-comparison group (Table 2).

The changes in per patient encounters over 5 years' post-intervention demonstrate that a larger reduction in hospitalizations occurred among CAI patients than among the full-comparison group (all P values for 5 years' post-intervention < 0.001). In contrast, the per patient ED encounter reductions over 5 years' post-intervention were similar across both CAI and full-comparison group patients (all P values for 5 years' post-intervention > 0.05) (Figure 1).

Intervention and high-cost subgroup cost differences

The severity matched high-cost subgroup had a lower per-patient cost reduction than the intervention group (Figure 2). Subtracting the high-cost subgroup cost reduction from the CAI cost reduction, the CAI patients had

Table 2. CAI and full comparison group per patient costs (data from 2005 to 2008, with follow-up through 2013).

CAI per Patient Cost		10/1/2005 to 6/30/2008				
N = 268	Baseline Year Cost (−1 year)	+1 Year Cost	+2 Year Cost	+3 Year Cost	+4 Year Cost	+5 Year Cost
	\$ 2,928	\$ 1,266	\$ 885	\$ 803	\$ 680	\$ 766
Cost Reduction from Baseline Year(P value)		\$ 1,662($P < 0.001$)	\$ 2,042($P < 0.001$)	\$ 2,125($P < 0.001$)	\$ 2,248($P < 0.001$)	\$ 2,161($P < 0.001$)
% Cost Reduction		57%	70%	73%	77%	74%
Full Comparison Group per Patient Cost		10/1/2005 to 6/30/2008				
N = 818	Baseline Year Cost (−1 year)	+1 Year Cost	+2 Year Cost	+3 Year Cost	+4 Year Cost	+5 Year Cost
	\$ 2,028	\$ 1,581	\$ 1,205	\$ 1,035	\$ 903	\$ 864
Cost Reduction(P value)		\$ 446($P = 0.083$)	\$ 823($P = 0.021$)	\$ 993($P = 0.008$)	\$ 1,125($P < 0.001$)	\$ 1,164($P < 0.001$)
% Cost Reduction		22%	41%	49%	55%	57%
Difference between CAI and Full Comparison Group per Patient Cost		10/1/2005 to 6/30/2008				
Adjusted Cost Reduction CAI – Full Comparison Group(P value)		+1 Year Cost	+2 Year Cost	+3 Year Cost	+4 Year Cost	+5 Year Cost
		\$ 1,216($P = 0.001$)	\$ 1,220($P < 0.001$)	\$ 1,132($P = 0.002$)	\$ 1,123($P = 0.004$)	\$ 997($P < 0.022$)

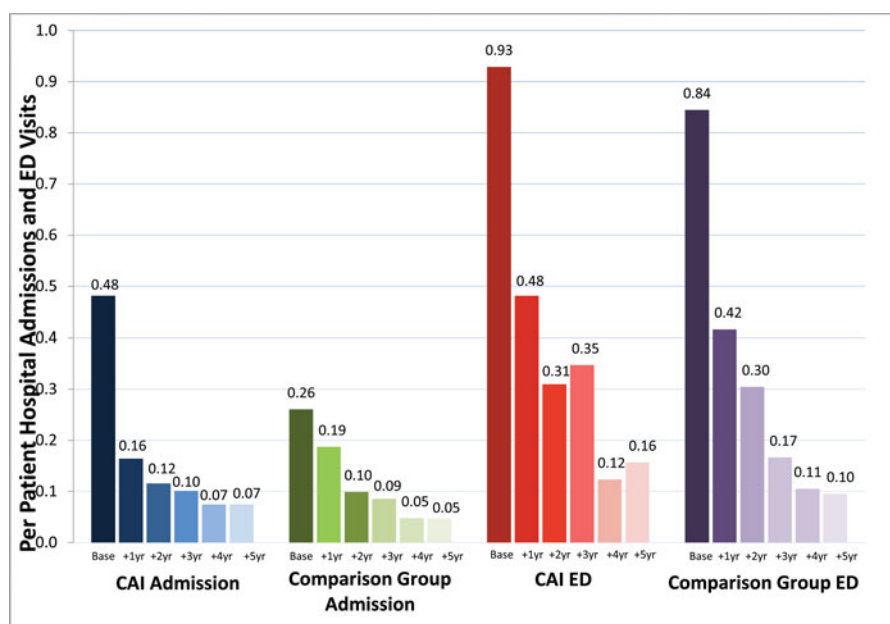


Figure 1. Hospitalizations and emergency department visits per patient for CAI and full comparison group patients for 5 years (data from 2005 to 2008 with follow-up through 2013). *Note.* P values for reduction of Admission from baseline year for all 5 years of follow-up among CAI patients were < 0.001 . P values for reduction of Admission from baseline year for all 5 years of follow-up among Full comparison group patients were < 0.001 . P values for difference in reduction of Admission between CAI and Full comparison group patients from baseline year for all 5 years of follow-up were < 0.001 . P values for reduction of ED visits from baseline year for all 5 years of follow-up among CAI patients were < 0.001 . P values for reduction of ED visits from baseline year for all 5 years of follow-up among Full comparison group patients were < 0.001 . P values for difference in reduction of ED between CAI and Full comparison group patients from baseline year for all 5 years of follow-up were as follows: +1 year ($P = 0.547$), +2 year ($P = 0.140$), +3 year ($P = 0.409$), +4 year ($P = 0.114$), +5 year ($P = 0.375$).

per patient cost reduction greater than the high-cost subgroup of \$1,152 in Year 1 ($P = 0.002$), \$1,042 in Year 2 ($P = 0.009$), \$808 ($P = 0.021$) in Year 3, \$815 ($P = 0.019$) in Year 4, and \$793 ($P = 0.023$) in Year 5 (Table 2). The higher CAI cost reductions followed a similar trend for both the high risk and full-comparison groups (Figure 1).

Adjusted return on investment (ROI) Using the full-comparison group

The net benefits in the form of NPV continued to increase over 5 years' post-intervention as an effect of the CAI program resulting in a net overall benefit of \$587,398

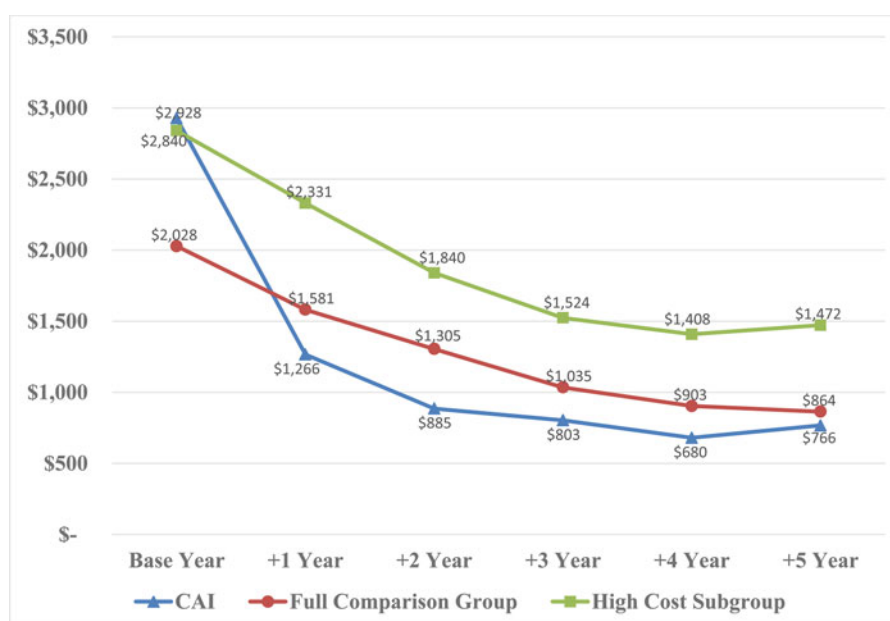


Figure 2. CAI, Full comparison group, and high cost subgroup per patient costs.

Table 3. ROI unadjusted and adjusted (adjusted by subtracting from the full comparison group).

	Per Month Savings	Total Present Value	Cumulative Present Value	NPV	ROI
Program Cost	(\$22,348)	(\$642,442)	(\$642,442)		
Unadj Cost Savings Year 1	\$37,118	\$422,199	\$422,199	(\$220,243)	0.66
Unadj Cost Savings Year 2	\$45,616	\$469,674	\$891,873	\$249,431	1.39
Unadj Cost Savings Year 3	\$47,455	\$442,294	\$1,334,167	\$691,725	2.08
Unadj Cost Savings Year 4	\$50,207	\$423,592	\$1,757,759	\$1,115,317	2.74
Unadj Cost Savings Year 5	\$48,270	\$368,652	\$2,126,410	\$1,483,968	3.31
Adj Cost Savings Year 1	\$27,151	\$308,824	\$308,824	(\$333,619)	0.48
Adj Cost Savings Year 2	\$29,478	\$303,516	\$612,339	(\$30,103)	0.95
Adj Cost Savings Year 3	\$25,283	\$235,643	\$847,982	\$205,540	1.32
Adj Cost Savings Year 4	\$25,090	\$211,682	\$1,059,664	\$417,222	1.65
Adj Cost Savings Year 5	\$22,282	\$170,176	\$1,229,840	\$587,398	1.91

over a 5-year period post-CAI intervention. The adjusted ROI results demonstrated a near break-even outcome at 2 years (2-year adjusted ROI = 0.95) and further continued higher returns at 3 years (adjusted ROI = 1.32), 4 years (adjusted ROI = 1.65), and 5 years (adjusted ROI = 1.91) (Table 3). This indicates that for every dollar spent on the CAI program, \$1.91 was saved by payers over a 5-year period.

Discussion

The findings of greater cost reductions from the CAI intervention group complement previously published literature on the benefits of community interventions. The results of this 5-year program analysis demonstrate consistent cost reduction that strengthens the business case for payers. Almost all of the cost reduction occurring over 5 years' post-intervention may be attributed to the higher reduction in hospitalizations among CAI patients than the full-comparison group patients. Calculating an adjusted return on investment provides a conservative estimate of the intervention cost saving. The results show that benefits from investments in community asthma case management and home visiting programs such as CAI can last for a considerable period post-intervention.

Our study demonstrates an average annual per patient adjusted cost reduction for CAI patients of \$1,200 over a 5-year post-intervention period. This finding is comparable to an annual per patient adjusted cost reduction from hospitalization and ED visits of \$1,100 reported in another recent study on pediatric asthma intervention [25]. The adjusted ROI and NPV, based on program cost and adjusted cost savings for the complete pilot phase, provide similar results as found in the first year of the pilot, and continues to demonstrate an ROI approaching one at two years after the original investment, with continued savings in future years [27,28]. The decrease may be attributed to improved asthma control leading to fewer asthma-related hospitalizations from CAI intervention.

When compared to a high-cost subgroup, the higher cost reductions among the intervention group were similar.

There were limitations to these analyses. CAI was not a randomized clinical trial but was an enhanced care implementation program that contained an intervention and a comparison group. A number of randomized clinical trials have demonstrated the importance of culturally appropriate, individualized care coordination, asthma education and coaching regarding importance of medication usage and adherence, and environmental assessment and remediation [17, 20, 25]. In the present analyses, reduction in costs only included hospital admission and ED costs based on hospital administrative data. Other costs such as primary and specialty physician costs, and pharmacy costs could not be included in the total cost estimates as these were not available in the hospital data. To address the limitations in the current study, future analyses have been planned in collaboration with a managed care organization (MCO) with full claims data that not only has complete data for ED visits and hospitalizations at all facilities (both children's hospital and outside health care) but also includes all costs of treatment including medication, outpatient, primary care, and specialty care costs.

The health care system in the United States, while increasingly recognizing the impact of social determinants of health on overall health and well-being, still devotes up to 95% of its health care dollars to direct medical services [9]. Addressing social determinants of health is particularly important for low-income patients, as supportive services and other non-clinical interventions can make a major difference in low-income patients' health and curb health care spending. CAI provided a comprehensive approach that integrated asthma education, case management, emotional support, and other non-medical interventions that contributed to improvements in asthma control and outcomes and parental quality of life [28]. Since CAI intervention are performed in home settings, the benefits are not simply limited

to the patient being targeted, but other family members also derive benefits and the overall return from the program are likely even higher than what is reported here.

Benefits from CAI intervention suggest that public health and community-based interventions should be considered within the scope of payment and health care delivery reforms. These services add significant value, yet have seldom been reimbursed by traditional fee-for-service methods, and have, therefore, had to rely primarily on grants and philanthropy that are time-limited and inconsistent. This study supports other investigators' findings that a defined set of services and partnerships with public health and community agencies, in addition to traditional clinical care, substantially improves outcomes in pediatric asthma, while providing a positive ROI [25]. The shift in health care financing towards alternative payment models, such as Accountable Care Organizations (ACO), that promise to reduce costs through an increased focus on the Triple Aim (health of populations, patient experience and quality, and reduced costs), is an opportunity for both payers and providers to re-design their care models to include Community Health Workers, home visits and other social and public health interventions that address the social determinants of health [35,36]. Boston Children's Hospital has entered into an ACO agreement with one Medicaid MCO and is planning for further alternative payment contracts in the future. CAI is being incorporated into the asthma population management planning and implementation as part of the ACO, in order to continue to reduce costly hospitalizations and ED visits.

Conclusion

This study demonstrated that CAI has improved health outcomes for asthma patients and has led to cost savings. Boston Children's Hospital and partners continue to work with Medicaid and other insurers to develop innovative payment models that can improve health outcomes for asthma while reducing costs. The positive adjusted ROI of 1.91 at 5 years following 1 year of intervention demonstrates to stakeholders that services that are traditionally considered social, community, or public health, not traditionally offered by the health care system, add value to care by supporting families with children with chronic diseases, like asthma, by addressing social determinants of health.

Declaration of interest

The authors report no conflicts of interest.

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