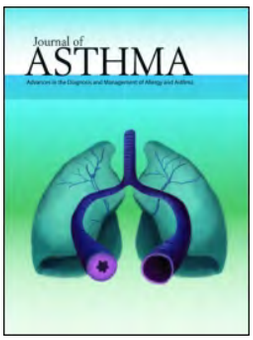


Journal of Asthma

ISSN: 0277-0903 (Print) 1532-4303 (Online) Journal homepage: https://www.tandfonline.com/loi/ijas20

Reducing potentially preventable health events among patients with asthma through multi-state, multi-center quality improvement program

Sirikan Rojanasarot, Angeline M Carlson, Wendy L St. Peter, Pinar Karaca-Mandic, Julian Wolfson & Jon C Schommer

To cite this article: Sirikan Rojanasarot, Angeline M Carlson, Wendy L St. Peter, Pinar Karaca-Mandic, Julian Wolfson & Jon C Schommer (2020): Reducing potentially preventable health events among patients with asthma through multi-state, multi-center quality improvement program, Journal of Asthma, DOI: 10.1080/02770903.2020.1741611

To link to this article: https://doi.org/10.1080/02770903.2020.1741611

Accepted author version posted online: 12 Mar 2020.

Article

Reducing potentially preventable health events among patients with asthma through multi-state, multi-center quality improvement program

Sirikan Rojanasarot, PhD[1], Angeline M Carlson, PhD[2], Wendy L St. Peter, PharmD, FCCP, FASN, FNKF[2], Pinar Karaca-Mandic, PhD[3], Julian Wolfson, PhD[4], Jon C Schommer, MS, PhD, RPh[2]

[1]Social and Administrative Pharmacy Graduate Program, Department of Pharmaceutical Care & Health Systems, College of Pharmacy, University of Minnesota

[2]Department of Pharmaceutical Care & Health Systems, College of Pharmacy, University of Minnesota

[3]Department of Finance, Carlson School of Management, University of Minnesota

[4]Division of Biostatistics, School of Public Health, University of Minnesota

Authors:

Sirikan Rojanasarot was a PhD candidate during the study period in the Social and Administrative Pharmacy Program, Department of Pharmaceutical Care & Health Systems, College of Pharmacy, University of Minnesota, Minneapolis, MN. Rojan003@umn.edu;

Angeline M Carlson is Professor in Department of Pharmaceutical Care & Health Systems, College of Pharmacy, University of Minnesota, Minneapolis, MN and director of research at Data Intelligence Consultants, LLC, Eden Prairie, MN. angie@dataiq.com;

Wendy L St. Peter is Professor in Department of Pharmaceutical Care & Health Systems, College of Pharmacy, University of Minnesota, Minneapolis, MN. stpet002@umn.edu;

Pinar Karaca-Mandic is Associate Professor in Department of Finance, Carlson School of Management, University of Minnesota, Minneapolis, MN. pkmandic@umn.edu;

Julian Wolfson is Assistant professor in Division of Biostatistics, School of Public Health, University of Minnesota, Minneapolis, MN. julianw@umn.edu;

Jon C Schommer is Professor in Department of Pharmaceutical Care & Health Systems, College of Pharmacy, University of Minnesota, Minneapolis, MN. schom010@umn.edu.

Corresponding Author: Sirikan Rojanasarot 136 Central Street, APT A2 Hudson, MA 01749. Phone: 612-402-7291. Email: rojan003@umn.edu; Sirikan.rojanasarot@gmail.com

Previous Presentation at Professional Meetings: The preliminary results of this work were presented as a podium presentation at the 2018 International Society for Pharmacoeconomic and Outcomes Research Annual International Meeting.

Abstract

Introduction: Enhancing Care for Patients with Asthma is a multi-state, multi-center quality improvement program developed to augment guideline-based practice among health care providers through Plan-Do-Study-Act cycle. This study examined the association between the implementation of the guideline-based quality improvement program and subsequent changes in asthma-related emergency room visits and hospitalizations.

Methods: This retrospective, interrupted time-series study used administrative claims data from a private insurer that provided coverage to patients receiving care from participating health centers (15 centers in New Mexico, Oklahoma, Texas, and Illinois). The 12-month implementation period

started in January 2013 for centers in Cohort 1 and October 2013 for centers in Cohort 2. The claims of 1,828 patients with asthma from January 2012 to May 2015 were analyzed. The data included 12-month pre-program implementation, 12-month program implementation, and 5-month post-program completion periods.

Results: The average number of asthma-related emergency room visits and hospitalizations decreased from 2.22 to 1.38 and 1.97 to 1.04 per 100 patients per month, respectively, in the 12-month pre-implementation period as compared to 12-month implementation period. The results of three-level generalized linear mixed models found that during the 12-month implementation period, patients had 37.7% and 47.1% lower rates of emergency room visits and hospitalizations, respectively, compared to the 12-month pre-implementation period ($p<0.001$ in both comparisons).

Conclusions: Enhancing Care for Patients with Asthma is an effective quality improvement program that was successfully executed in diverse geographical states and associated with reductions in potentially preventable health events. The findings support widespread of the program in other settings.

Keywords: Epidemiology, Control/Management, Treatment, Pediatrics

Introduction

Emergency room (ER) visits and hospitalizations are frequent for patients with asthma.[1] These events are potentially preventable public health problems and major contributors to the high costs of health care.[2] Since these events are usually avoidable with proper asthma management,[3] high-quality asthma care is needed to assist patients in living better with this chronic condition.

Although asthma care provided in community settings plays a critical role in achieving optimal patient outcomes, previous research has reported several barriers to adoption of management guidelines into the practice settings.[4–6] The barriers include the lack of time and necessary

equipment[4] and non-familiarity with specific guideline elements.[5] The Expert Panel Report 3 (EPR-3) guidelines have outlined essential asthma care components for appropriate asthma management.[7] However, asthma care quality remains suboptimal[8] due in part to the underutilization of evidence-based asthma guidelines. Therefore, an effective quality improvement action that facilitates the implementation of guideline recommendations would translate into reducing potentially preventable ER visits and hospitalizations.

Enhancing Care for Patients with Asthma (ECPA) is a multi-state, multi-center quality improvement program that was developed to augment guideline-based asthma care processes in health centers in four states: Illinois, New Mexico, Oklahoma, and Texas.

Previous research has demonstrated the effectiveness of ECPA in improving clinic-based performance measures consistent with the EPR-3 guidelines.[9] It is unknown if the program is associated with a decrease in ER visits and hospitalizations among patients with asthma. Therefore, the objective of this study was to examine the association between the implementation of ECPA and subsequent changes in asthma-related health events. The hypothesis was that patients with asthma who received care from health centers that participated in ECPA would have lower numbers of ER visits and hospitalizations after program implementation.

Methods

Study Design

This study employed a retrospective quasi-experimental approach using an interrupted time series (ITS) design. The ITS design has been recommended for evaluation of health care interventions having a clear implementation segment.[10] ECPA divided the recruitment and participation of centers into different chronological cohorts. The ECPA implementation could be considered as a multiple ITS given the sequential introduction of ECPA in different health center cohorts. Each ECPA cohort started and completed the quality improvement activities within a well-defined month. The ITS

approach is also appropriate for the ECPA program evaluation because the sequential measures of the outcome are available both before, during, and after program implementation.[10]

Setting

ECPA was executed in participating health centers at Illinois, New Mexico, Oklahoma, and Texas. Three-fourths of the participating health centers were in an urban area. The centers included stand-alone primary care clinic (36.9%), stand-alone pediatric clinic (18.5%), multi-specialty health center (23.1%), and school-based or mobile clinic (21.5%). Health centers agreed to participate in ECPA were evaluated to ensure their commitment to the 12-month quality improvement program. During a 12-month implementation period, ECPA assisted participating health centers with improvement activities through the Plan-Do-Study-Act (PDSA) cycle to carry out changes that led to asthma guidelines adoption in each center. The ECPA support involves both clinical and technical assistance, such as providing centers with a spirometer used to assess patients' lung function and properly monitor asthma control and training clinic staff in key guideline components required for patients with asthma. Each cohort had at least one center from each state to ensure the high quality of the improvement effort. The full description of the program is published elsewhere.[9] This analysis concentrated on 15 health centers in Cohort 1 and Cohort 2 of ECPA. For Cohort 1, the 12-month implementation period started in January 2013 for all centers. For Cohort 2, the 12-month implementation period started in October 2013 for centers in New Mexico and Texas, and in January 2014 for centers in Illinois.

Data Source

This study used administrative claims from a private insurance company that provided coverage to enrollees who received care in ECPA-participating health centers. Patient enrollment and hospital and office-based claims data from January 2012 to May 2015 were provided for analysis. The dataset

was fully de-identified and HIPAA (Health Insurance Portability and Accountability Act of 1996) compliant.

The administrative claims dataset covered the 12-month period before ECPA implementation in Cohort 1 and ended five months after ECPA completion in Cohort 2. Therefore, this study divided observations into three segments: 12-month pre-ECPA implementation, 12-month ECPA implementation, and 5-month post-ECPA completion. The comparison of outcomes in each segment allowed the investigation of ECPA effect while improvement activities were ongoing in each health center and after program completion with no structural support from the program. Figure 1 summarizes administrative claims availability of this study.

Participants

Eligible patients were identified and attributed to a participating health center using the following inclusion criteria: continuously enrolled from January 1, 2012, to May 31, 2015; had at least one claim at a participating health center during the 12-month pre-implementation period with a primary or secondary diagnosis of asthma (International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) code of 493.xx). Patients were excluded if they disenrolled from their insurance plans between January 2012 and May 2015. Patients who could be attributed to more than one health center were assigned to the health center they visited more frequently.

Outcomes of Interest

The outcome of interest was ER visits and hospitalizations with a primary or secondary diagnosis of asthma (ICD-9-CM code 493.xx). ER visits were defined using Current Procedural Terminology (CPT) code 99281-5. Hospitalizations were defined using Place of Service (POS) code 21 and revenue codes indicating hospital services (11x-48x). An ER visit that resulted in hospitalization was counted as a hospitalization episode. Asthma-related ER visits and hospitalizations were then

constructed into: 1) combined number of both events per patient per month; 2) number of ER visits per patient per month; and 3) number of hospitalizations per patient per month.

Statistical Methods

Descriptive Statistics

Patient baseline demographics were reported by state. Patients' age at baseline was referred to as the patient age one year before the ECPA implementation at their attributed center was executed. To clarify, the baseline age of all patients equaled their age in 2012, except the patients who received asthma care from Illinois health centers in the second cohort. The baseline age of these Illinois patients equaled their age in 2013. The age was calculated and described using mean, standard deviation, median, interquartile range, minimum, and maximum values. The percentage of patients aged less than 18 was reported. Patient percent by gender was calculated.

To combine the number of ER visits and hospitalizations from both ECPA cohorts, a dummy variable was created for the month when outcomes were observed that was centered for each cohort; zero corresponded to the last observation of the pre-ECPA implementation period (values range from -11 to 17). The average numbers of ER visits and hospitalizations during 12-month pre-implementation and 12-month implementation periods were calculated by dividing the total number of the events occurred during the 12-month periods by the total, fixed number of patients who received asthma care from the participating health centers. Time series plots of observed combined number of ER visits and hospitalizations and predicted trend of the health events estimated from modeling the time series with ITS design were presented to identify the underlying trend.[10]

Statistical Inferences

To determine ECPA effect on outcomes, the 3-level generalized linear mixed model (GLMM) was selected because of the three nested levels and repeated time series data of this study. Within the

same patient, ER visit and hospitalization numbers from different months are correlated and considered the level-1 measurement. These numbers are nested within that patient, which is the level-2 cluster. Patients from the same health center are also nested in that center, which is the level-3 cluster. This study allows individual patients and individual participating health centers to have their own random intercepts to partition their variation.

The 3-level GLMM permits investigation of the within-patient effect and quantification of improvement in ER visits and hospitalizations for three comparisons. First, outcomes between pre-ECPA implementation and 12-month ECPA implementation periods were compared to determine the effect of ECPA while it actively supported health centers. Second, outcomes between pre-ECPA implementation and 5-month post-ECPA completion periods were compared to determine the short-term, sustainable effect of ECPA during no active support to health centers following program completion. Third, outcomes between 12-month ECPA implementation and 5-month post-ECPA completion periods were compared to determine if there were statistically significant differences in the outcomes between the two segments. The effectiveness of ECPA from these three comparisons were reported using rate ratio (RR), 95% confidence interval (CI), and p-value.

Seasonality is an environmental factor widely acknowledged in asthma research.[11] Therefore, a dummy variable for season was included: winter (December-February), spring (March-May), summer (June-August), and fall (September-November).[12] The ITS design is not impacted by the common, non-time-dependent covariates such as age, gender, race or ethnicity, or educational level.[10] Thus, these standard covariates were not included in final statistical models.

All statistical analyses were performed using SAS version 9.3 (SAS Institute Inc., Cary, NC, USA).[13] The number of ER visits and hospitalizations are count data. The GLMM estimates assumed Poisson distribution and its canonical log link to determine the ECPA effect. Poisson distribution was appropriate since the data used for this study did not present overdispersion after the scaled Pearson statistic for the conditional distribution of each GLMM was tested.[13] All models included seasonality

as a confounding factor. An estimation of the parameters was achieved using a PROC GLIMMIX.[14] A significance level of less than 0.05 (2-tailed) was adopted for all analyses. This study was considered exempt by the institutional review board of the University of Minnesota due since we used de-identified existing administrative claims data.

Subgroup Analysis

The claims segment submitted until December 2014 was used for subgroup analysis in Cohort 1 to investigate whether there was a longer-term, sustainable effect of ECPA on ER visits and hospitalizations 12 months post-ECPA completion.

Results

Table 1 summarizes the baseline characteristics of 1,828 patients who received asthma care from the 15 health centers participating in the two cohorts of ECPA. Illinois and New Mexico had the highest number of participating health centers. Patients from New Mexico had the highest average age of 42.3 years, compared to the other states. The number of male and female patients from each state was comparable.

Figure 2 shows the ITS analysis of the crude number of ER visits and hospitalizations due to asthma of the 1,828 included patients before and after ECPA implementation. Before ECPA was implemented, the asthma-related ER visits and hospitalizations demonstrated an upward trend with the slope of 0.45. After ECPA was implemented in participating health centers, ER visits and hospitalizations decreased showing a downward trend with the slope of -0.06. The slopes were statistically different ($p<0.001$).

The average numbers of ER visits and hospitalizations due to asthma decreased from 2.22 to 1.38 and 1.97 to 1.04 times per 100 patients per month, respectively, in the 12-month pre-implementation period as compared to 12-month ECPA implementation period. The average numbers of ER visits

and hospitalizations during the 5-month post-program completion phase were 1.02 and 1.09 times per 100 patients per month, respectively.

The ECPA effect from the 3-level GLMM analyses on the rates of health events due to asthma after accounting for seasonality is depicted in Table 2. RRs represent the change in outcome occurrence comparing a particular period to a reference period. During the 12-month ECPA implementation period, patients had 42.1%, 37.7%, and 47.1% lower rates of combined asthma-related ER visits or hospitalizations, ER visits alone, and hospitalizations alone, respectively, compared to the patients during the 12-month pre-implementation period ($p<0.001$ in all three comparisons).

When comparing the implementation and post-program completion segments, the rate of ER visits alone was significantly lower (RR=0.728; 95% CI 0.562, 0.942; p=0.0158). However, this was not the case for combined hospitalizations and ER visits (RR=0.848; 95% CI 0.705, 1.022; p=0.0828) or hospitalizations alone (RR=1.005; 95% CI 0.768, 1.315; p=0.9701).

In addition to the main analyses, the subgroup analyses focusing on 1,683 patients from Cohort 1 found that the average rates of ER visits and hospitalizations due to asthma as a primary or secondary diagnosis decreased from 2.17 to 1.28 and 1.94 to 1.01 per 100 patients per month, respectively, in the 12-month pre-implementation period as compared to 12-month ECPA implementation period. The average rates of ER visits and hospitalizations during the 12-month post-program completion phase were 0.97 and 1.05 per 100 patients per month, respectively. The results from the GLMM analyses are reported in Table 3. The rate ratio of the three outcomes ranged from 0.448 (ER visits) to 0.542 (hospitalizations) when comparing the event rates of pre-implementation to post-program completion periods. Using the implementation period as a reference, the rates of ER visits alone significantly decreased during the 12-month post-program completion period (RR=0.758; 95% CI 0.634, 0.906; p=0.0023).

Discussion

This analysis of the effectiveness of a multi-state, multi-center, quality improvement program for patients with asthma showed that implementation of Enhancing Care for Patients with Asthma (ECPA), a quality improvement program designed to improve asthma care processes at the clinic level, was associated with significant reduction of asthma-related ER visits and hospitalizations. The numbers of ER visits and hospitalizations in the implementation and post-program completion periods were decreased roughly by half, compared to rates 12 months before ECPA implementation. From the 3-level GLMM, the magnitude of the program effect was greater on the rate of ER visits when focusing on the improvement from pre-implementation to post-program completion periods (more than 50% reduction in the ER visit rate). Subgroup analysis also demonstrated a potential long-term, sustainable effect of ECPA on asthma-related adverse events*;* patients, attributed to health centers in Cohort 1 were less likely to experience asthma-related outcomes in the 12-month post-program completion period. The results of this study provided substantial evidence for the effective, translational effect of ECPA on patient outcomes.

The findings regarding the translational effect of ECPA is critically important in quality improvement approaches that target the quality of asthma care at the health center level, given the high impact of the program effect on the patient outcomes. Woods et al. investigated the effectiveness of a quality improvement program through nurse case management and home visits.[15] While their program demonstrated a decrease in the number of ER visits and hospitalizations after patients engaged in the program, home visits can be time-consuming and expensive. ECPA, instead, concentrated on improving guideline-based asthma care processes in health centers. With approximately 50% improvement in ER visits and hospitalizations, ECPA established its translational effect on patient-level outcomes and appropriateness for being replicated at a population level.

The highest magnitude of ECPA effect (comparing post-program completion to pre-implementation periods) was on preventing ER visits. Asthma-related ER visits are mostly preventable[16] with proper asthma management. Comprehensive asthma care could improve asthma symptoms[17] and decrease

asthma exacerbation[18] and ER visit rates.[19] In previous work, ECPA showed impact on improving asthma guideline-based performance measures, such as documentation of asthma action plan, asthma education, and controller medication.[9] Improvement in these essential care components among patients receiving care from ECPA-participating health centers most likely contributed to minimizing asthma-related ER visits.

Although previous research demonstrated that hospitalizations per capita and ER visits per capita have been declining nationally in the study period,[20] the national average trend including individuals with different health insurance types might not well represent patients with asthma with private insurance coverage. In this research the population of interest was those with asthma who had private health insurance from 4 states: Illinois, New Mexico, Oklahoma, and Texas. The majority of included patients were derived from the participating Illinois health centers in Cohort 1 (61%; 1,121/1,828). The State Inpatient Database and of the Healthcare Cost and Utilization Project (HCUP) for Illinois documented a relatively stable trend, rather than decreased trend, of asthma-related hospitalization[21] and ER visits[22] among patients with asthma with private health insurance in Illinois during the same study periods (January 2012 to December 2014). The specific trend among patients with asthma with private health insurance at the state level was stable, but the findings of this study showed the declining trend after ECPA, the results suggest the health care utilization improvement was attributable to the quality improvement efforts.

One strength of this study is that the analyses evaluated the effect of ECPA through multiple aspects, showing program generalizability. ECPA decreased asthma-related outcomes while the program was ongoing in participating centers and after program had been completed (5-month short-term effect and 12-month long-term effect). These results support internal validity of ECPA in improving patient outcomes.[23] Moreover, ECPA was shown to be a generalizable program demonstrating external validity in multiple health centers with various characteristics in four different states.[9] This study provides a further understanding of ECPA's generalizability. The study could also enable decision-

makers in supporting effective quality improvement programs for patients with asthma and overcoming the sustainability issue seen in previous quality improvement efforts.[24]

Another strength of this study is the evaluation of ER visits and hospitalizations: outcomes that have not been observed much in quality improvement interventions. A systematic review by Peytremann-Bridevaux et al. reported that less than half of published studies they examined evaluated the improvement in ER visits and hospitalizations among patients with asthma[25] and these are important outcomes to consider when evaluating effects of asthma management programs. This study evaluated ECPA effect on potentially preventable asthma-related health events. Since these outcomes are less often observed in the evaluation of quality improvement programs, this study provides meaningful evidence to the scientific community.

Three limitations should also be noted. First, the data source was secondary, administrative claims data. While these data enabled examination of outcomes patient outcomes across multiple health centers, administrative data is subject to coding errors.[26] Second, this study used the provider tax identification number of participating health centers to attribute patients to each center. Some clinic locations shared the same identification number. Thus, we could not attribute patients to a specific location and could not include the location data as a random intercept. Third, while the GLMM analyses of this study include seasonality as an adjusting covariate, other unobserved time-varying factors, such as outdoor air pollution,[27] could contribute to asthma exacerbation and result in the use of ERs or admission to a hospital. However, this problem is relatively small because of ITS approach, which is not affected by a time-varying confounder that is relatively constant over a short-time period.[10] Despite these limitations, this study provides insights into a multi-state, multi-center quality improvement strategy that mitigates potentially preventable health events among patients suffering from asthma.

Conclusion

ECPA is an effective quality improvement program which was associated with reductions in asthma-related ER visits and hospitalizations. ECPA effects on asthma-related health events were sustainable in the 12-month period post-program completion. These findings augment previous research that showed the effectiveness of ECPA on asthma guideline-based performance measures and supplied evidence for widespread the ECPA implementation. Further research could build on the body of literature by investigating whether ECPA could also reduce overall health care expenditure among patients with asthma.

Potential Conflicts of Interest Disclosure: Dr. Rojanasarot is a full-time employee of Boston Scientific. Dr. Karaca-Mandic provides consulting services to Precision Health Economics and Tactile Medical. These consulting activities do not have a relation to the manuscript. The other authors have no conflict of interest.

Acknowledgments

The authors would like to thank Health Care Service Corporation for the provision of the administrative claims data used in this study.

References

1. Andrews AL, Simpson AN, Basco WT, Teufel RJ. Asthma medication ratio predicts emergency department visits and hospitalizations in children with asthma. *Medicare & Medicaid Research Review*. 2013;3(4). doi:10.5600/mmrr.003.04.a05.

2. Akinbami LJ, Sullivan SD, Campbell JD, et al. Asthma outcomes: Healthcare utilization and costs. *J Allergy Clin Immunol.* 2012;129(3 0):S49–64.

3. Barrett M, Wier L, Washington R. Trends in pediatric and adult hospital stays for asthma, 2000–2010. Rockville, MD: Agency for Healthcare Research and Quality. Statistical Brief# 169.

4. Gagné ME, Boulet L-P. Implementation of asthma clinical practice guidelines in primary care: A cross-sectional study based on the Knowledge-to-Action Cycle. *J Asthma.* 2018;55(3):310–7.

5. Wisnivesky JP, Lorenzo J, Lyn-Cook R, et al. Barriers to adherence to asthma management guidelines among inner-city primary care providers. *Ann Allergy Asthma Immunol*. 2008;101(3):264–70.

6. Okelo SO, Butz AM, Sharma R, et al. Interventions to modify health care provider adherence to asthma guidelines: A systematic review. *Pediatrics.* 2013;132(3):517–34.

7. National Heart, Lung, and Blood Institute. Expert panel report 3—Guidelines for the diagnosis and management of asthma: Full report. US Department of Health and Human Services, National Institutes of Health, National Heart, Lung, and Blood Institute.; 2007.

8. Mangione-Smith R, DeCristofaro AH, Setodji CM, et al. The quality of ambulatory care delivered to children in the United States. N Engl J Med. 2007 Oct 11;357(15):1515–23.

9. Rojanasarot S, Heins Nesvold J, Carlson AM, et al. Enhancing guideline-based asthma care processes through a multi-state, multi-center quality improvement program. *J Asthma.* 2018 Apr 11:1-11. doi: 10.1080/02770903.2018.1463378.

10. Lopez Bernal J, Cummins S, Gasparrini A. Interrupted time series regression for the evaluation of public health interventions: A tutorial. *Int J Epidemiol.* 2017;46(1):348-55.

11. Johnston NW, Sears MR. Asthma exacerbations 1: Epidemiology. *Thorax.* 2006;61(8):722–8.

12. Buckley JP, Richardson DB. Seasonal modification of the association between temperature and adult emergency department visits for asthma: A case-crossover study. *Environ Health.* 2012;11(1):55.

13. SAS Institute Inc. Example 38.14: Generalized Poisson mixed model for overdispersed count data. SAS/STAT(R) 9.2 User's Guide, Second Edition.

https://support.sas.com/documentation/cdl/en/statug/63033/HTML/default/viewer.htm#statug_glimmix_sect026.htm

14. Austin PC. Estimating multilevel logistic regression models when the number of clusters is low: A comparison of different statistical software procedures. *Int J Biostat*. 2010;6(1).

15. Woods ER, Bhaumik U, Sommer SJ, et al. Community asthma initiative: Evaluation of a quality improvement program for comprehensive asthma care. *Pediatrics.* 2012;129(3):465-72.

16. Agency for Healthcare Research and Quality. Measures of care coordination: Preventable emergency department visits. Rockville, MD; 2015. Available from: http://www.ahrq.gov/research/findings/nhqrdr/2014chartbooks/carecoordination/carecoord-measures2.html

17. Rojanasarot S, Carlson AM. The medical home model and pediatric asthma symptom severity: Evidence from a national health survey. *Popul Health Manag*. 2017 Aug 14.

18. Couturaud F, Proust A, Frachon I, et al. Education and self-management: A one-year randomized trial in stable adult asthmatic patients. *J Asthma.* 2002;39(6):493–500.

19. Kercsmar CM, Beck AF, Sauers-Ford H, et al. Association of an asthma improvement collaborative with health care utilization in Medicaid-insured pediatric patients in an urban community. *JAMA Pediatr*. 2017 Nov 1;171(11):1072–80.

20. Sun R, Karaca Z, Wong HS. Trends in hospital inpatient stays by age and payer, 2000–2015: Statistical Brief #235. In: Healthcare Cost and Utilization Project (HCUP) Statistical Briefs. Rockville (MD): Agency for Healthcare Research and Quality (US); 2006.

21. Healthcare Cost and Utilization Project (HCUP). HCUP Fast Stats - State Trends in Inpatient Stays by Payer. Rockville, MD.: Agency for Healthcare Research and Quality Available from: https://www.hcup-

us.ahrq.gov/faststats/StatePayerServlet?state1=IL&type1=CN03&combo1=s&state2=&type2=PY00&combo2=s&expansionInfoState=hide&dataTablesState=hide&definitionsState=hide&exportState=hide

22. Healthcare Cost and Utilization Project (HCUP). HCUP Fast Stats - State Trends in Emergency Department Visits by Payer. Agency for Healthcare Research and Quality. Rockville, MD.: Agency for Healthcare Research and Quality. Available from: https://www.hcup-us.ahrq.gov/faststats/StatePayerEDServlet?state1=IL&type1=CN09P&combo1=s&state2=&type2=PY00B&combo2=s&expansionInfoState=hide&dataTablesState=hide&definitionsState=hide&exportState=hide

23. Øvretveit J, Leviton L, Parry G. Increasing the generalisability of improvement research with an improvement replication programme. *BMJ Qual Saf.* 2011;20(Suppl 1):i87–91.

24. Dixon-Woods M, McNicol S, Martin G. Ten challenges in improving quality in healthcare: Lessons from the Health Foundation's programme evaluations and relevant literature. *BMJ Qual Saf.* 2012;21(10):876–84.

25. Peytremann-Bridevaux I, Arditi C, Gex G, Bridevaux P-O, Burnand B. Chronic disease management programmes for adults with asthma. *Cochrane Database Syst Rev.* 2015;(5):CD007988.

26. Johnson EK, Nelson CP. Utility and pitfalls in the use of administrative databases for outcomes assessment. *J Urol.* 2013;190(1):17–8.

27. Guarnieri M, Balmes JR. Outdoor air pollution and asthma. *Lancet.* 2014;383(9928):1581–92

Table 1: Baseline demographic characteristics of patients receiving asthma care from participating health centers

Characteristics	Total	Illinois	New Mexico	Oklahoma	Texas
Health centers (n=15)	15 (100.0%)	6 (40.0%)	6 (40.0%)	2 (13.3%)	1 (6.7%)
Cohort 1	9 (60.0%)	4 (44.4%)	3 (33.3%)	2 (22.2%)	0 (0.0%)
Cohort 2	6 (40.0%)	2 (33.3%)	3 (50.0%)	0 (0.0%)	1 (16.7%)
Patients (n=1,828)	1,828 (100.0%)	1,135 (62.1%)	580 (31.7%)	64 (3.5%)	49 (2.7%)
Cohort 1	1,683 (92.1%)	1,121 (98.8%)	498 (85.9%)	64 (100.0%)	0 (0.0%)
Cohort 2	145 (7.9%)	14 (1.2%)	82 (14.1%)	0 (0.0%)	49 (100.0%)
Baseline age, years					
Mean (SD)	30.5 (23.9)	25.6 (23.0)	42.3 (22.1)	29.2 (21.7)	8.4 (4.5)
Median	19	15	48	25	8
Interquartile range	9-52	8-45	19-61	11-47	5-12
Minimum-Maximum	1-93	1-93	1-90	1-81	1-17
Age less than 18 (%)	861 (47.1%)	656 (57.8%)	131 (22.6%)	25 (39.1%)	49 (100.0%)
Gender					
Female	999 (54.7%)	583 (51.4%)	366 (63.1%)	33 (51.6%)	17 (34.7%)
Male	829 (45.3%)	552 (48.6%)	214 (36.9%)	31 (48.4%)	32 (65.3%)

SD=Standard deviation

Due to rounding, percentages may not always add up to 100%.

Table 2: ECPA effect on emergency room visits and hospital hospitalizations among 1,828 included patients after adjusting for seasonality from the 3-level generalized linear mixed model

Outcomes	ECPA effect	Rate ratio	95% CI		p-value
Either emergency room visit or hospitalization	12-month pre-implementation	Ref	N/A	N/A	N/A
	12-month implementation	0.579	0.520	0.644	<.0001*
	5-month post-completion	0.500	0.422	0.591	<.0001*
Emergency room visit alone	12-month pre-implementation	Ref	N/A	N/A	N/A
	12-month implementation	0.623	0.540	0.719	<.0001*
	5-month post-completion	0.443	0.350	0.562	<.0001*
Hospitalization alone	12-month pre-implementation	Ref	N/A	N/A	N/A
	12-month implementation	0.529	0.450	0.621	<.0001*
	5-month post-completion	0.567	0.446	0.720	<.0001*

CI=Confidence interval; ECPA=Enhancing Care for Patients with Asthma; N/A=Not applicable;

Ref=Reference

Generalized linear mixed regression assuming Poisson distribution and its canonical log link was used to estimate the effect of ECPA on the three outcomes, accounting for seasonality.

Example of interpretation:

- On average, patients had a 42.1% lower rate of combined emergency room visits or hospitalizations during the 12-month ECPA implementation period, compared to the 12-month pre-implementation period.

Asterisks indicate a statistically significant result at a significance level of 0.05.

Table 3: Subgroup analyses of the Cohort 1-ECPA effect among 1,683 patients on emergency room visits and hospitalizations after adjusting for seasonality from the 3-level generalized linear mixed model

Outcomes	ECPA effect	Rate ratio	95% CI		p-value
Either emergency room visit or hospitalization	12-month pre-implementation	Ref	N/A	N/A	N/A
	12-month implementation	0.560	0.502	0.624	<.0001*
	12-month post-completion	0.492	0.439	0.552	<.0001*
Emergency room visit alone	12-month pre-implementation	Ref	N/A	N/A	N/A
	12-month implementation	0.591	0.510	0.685	<.0001*
	12-month post-completion	0.448	0.381	0.527	<.0001*
Hospitalization alone	12-month pre-implementation	Ref	N/A	N/A	N/A
	12-month implementation	0.525	0.446	0.617	<.0001*
	12-month post-completion	0.542	0.461	0.636	<.0001*

CI=Confidence interval; ECPA=Enhancing Care for Patients with Asthma; N/A=Not applicable; Ref=Reference

Generalized linear mixed regression assuming Poisson distribution and its canonical log link was used to estimate the effect of ECPA on the three outcomes, as subgroup analyses focusing only on patients receiving asthma care from Cohort-1 health center.

Example of interpretation:

- On average, patients had a 44.0% lower rate of combined emergency room visits or hospitalizations during the 12-month ECPA implementation period, compared to the 12-month pre-implementation period.

Asterisks indicate a statistically significant result at a significance level of 0.05.

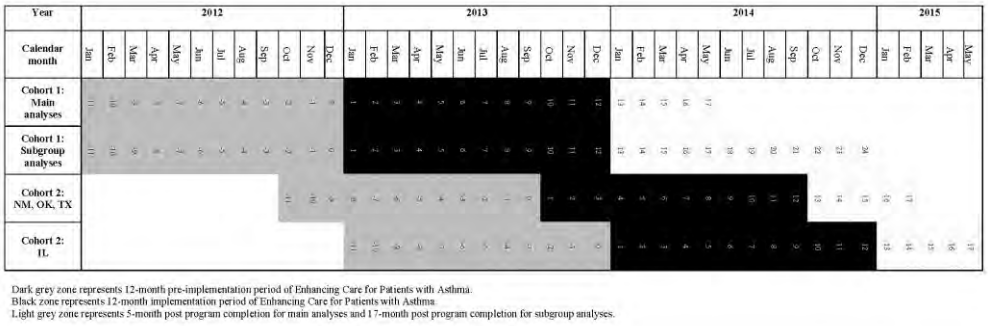
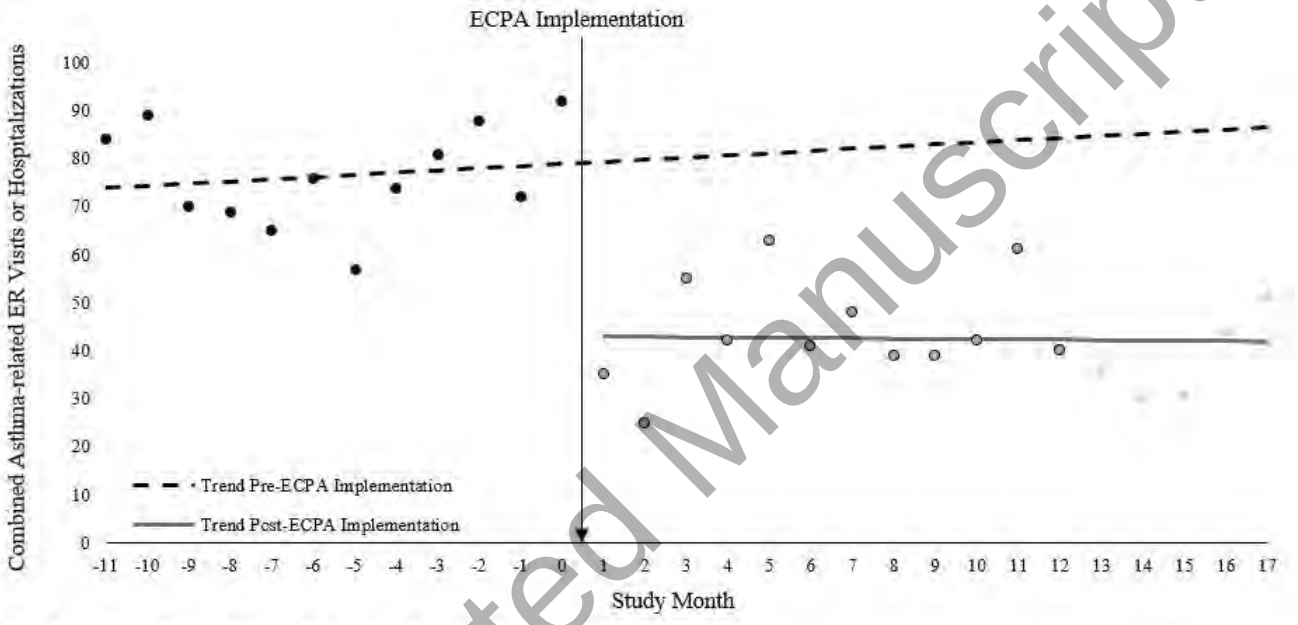


Figure 1: The summary of administrative claims availability of this study



ER, Emergency Room; ECPA, Enhancing Care for Patients with Asthma
The scatter plots represented actual numbers of asthma-related emergency room visits or hospitalizations at different time periods.

Figure 2: Monthly number of combined asthma-related emergency room visits or hospitalizations among 1,828 included patients