# Follow-Up After Asthma Emergency Department Visits and Its Relationship With Subsequent Asthma-Related Utilization

*Naomi S. Bardach, MD, MAS; Valerie S. Harder, MHS, PhD; Charles E. McCulloch, PhD; Robert Thombley, BS; Judith S. Shaw, EdD, MPH, RN; Victoria C. Hart, MS, PhD; Michael D. Cabana, MD, MPH*

From the Department of Pediatrics (NS Bardach), University of California, San Francisco, Calif; Philip R. Lee Institute for Health Policy Studies (NS Bardach and R Thombley), University of California, San Francisco, Calif; Department of Pediatrics (VS Harder and JS Shaw), University of Vermont, Burlington, Vt; Department of Epidemiology and Biostatistics (CE McCulloch), University of California, San Francisco, Calif; Department of Medicine (VC Hart), University of Vermont, Larner College of Medicine, Burlington, Vt; and Albert Einstein College of Medicine and the Children's Hospital at Montefiore (MD Cabana), New York City, NY
The authors have no conflicts of interest relevant to this article to disclose.
Address correspondence to Naomi S. Bardach, MD, MAS, Philip R Lee Institute for Health Policy Studies, University of California, San Francisco, 490 Illinois St., San Francisco, CA 94158 (e-mail: naomi.bardach@ucsf.edu).
Received for publication February 8, 2021; accepted October 30, 2021.

## Abstract

***Objective:*** To assess the association between follow-up after an asthma-related emergency department (ED) visit and the likelihood of subsequent asthma-related ED utilization.

***Methods:*** Using data from California Medicaid (2014−2016), and Vermont (2014−2016) and Massachusetts (2013−2015) all-payer claims databases, we identified asthma-related ED visits for patients ages 3 to 21. Follow-up was defined as a visit within 14 days with a primary care provider or an asthma specialist. Outcome: asthma-related ED revisit after the initial ED visit. Models included logistic regression to assess the relationship between 14-day follow-up and the outcome at 60 and 365 days, and mixed-effects negative binomial regression to assess the relationship between 14-day follow-up and repeated outcome events (# ED revisits/100 child-years). All models accounted for zip-code level clustering.

***Results:*** There were 90,267 ED visits, of which 22.6% had 14-day follow-up. Patients with follow-up were younger and more likely to have commercial insurance, complex chronic conditions, and evidence of prior asthma. 14-day follow-up was associated with decreased subsequent asthma-related ED revisits at 60 days (5.7% versus 6.4%, $P < .001$) and at 365 days (25.0% versus 28.3%, $P < 0.001$). Similarly, 14-day follow-up was associated with a decrease in the rate of repeated subsequent ED revisits (66.7 versus 77.3 revisits/100 child-years; $P < 0.001$).

***Conclusions:*** We found a protective association between outpatient 14-day follow-up and asthma-related ED revisits. This may reflect improved asthma control as providers follow the NHLBI guideline stepwise approach. Our findings highlight an opportunity for improvement, with only 22.6% of those with asthma-related ED visits having 14-day follow-up.

**Keywords:** access; asthma; emergency department; follow-up; quality measurement; utilization

**Academic Pediatrics** 2022;22:S125−S132

## What's New

For children and adolescents with an asthma-related emergency department visit, having follow-up within 14 days is associated with lower rates of subsequent asthma-related ED revisits in the short-term (within 60 days) and the long-term (within 365+ days).

Clinical practice guidelines for the management of asthma recommend that patients be referred for a follow-up within 1 to 4 weeks with their primary care provider or asthma specialist after being treated in the emergency department (ED) for an asthma exacerbation.[1−3] An urgent ED visit for asthma may indicate a need for daily asthma medications, patient difficulty in recognizing asthma symptoms, difficulty managing asthma symptoms triggers, or any number of clinical issues. As a result, follow-up care for additional patient education, pharmacologic therapy or environmental control could help decrease the likelihood of a repeat ED visit.

Some prior research has not demonstrated a beneficial association with outpatient follow-up after an ED asthma visit. For example, a retrospective cohort study of children found that an outpatient follow-up visit with any provider after an asthma-related ED visit was paradoxically associated with *increased* ED use in the follow-up year.[4] Liberman et al[5] noted no association between primary care follow-up within 30 days and decreased ED revisits for asthma over the next year. Baren et al conducted a randomized controlled trial of ED interventions to improve primary care follow-up for patients aged 2 to 54 years with acute asthma. Although the interventions were able

**Table 1.** Asthma ICD Codes

| | |
|---|---|
| ICD-9 asthma-related codes used | '49300′,'49301′,'49302′,'49310′,'49311′,'49312′,'49320′,'49321′, '49322′, '49381′,'49382′,'49390′,'49391′,'49392′ |
| ICD-10 asthma-related codes used | 'J4520′,'J4521′,'J4522′,'J4530′,'J4531′,'J4532′,'J4540′,'J4541′, 'J4542′,'J4550′,'J4551′,'J4552′,'J45901′,'J45902′,'J45909′, 'J45990′,'J45991′,'J45998′ |

to improve follow-up rates with primary care physicians, there were no differences in ED revisits or hospitalizations 1 year after the index ED visit (and median age was 23).[6] Zorc et al[7] performed a single-site RCT in 1999−2000 to schedule primary care follow-up after pediatric asthma-related ED visit, and found no association between the intervention group and subsequent ED utilization at 4 weeks. However, in the last decade, methods to improve outpatient asthma management and education have evolved and elements of a successful follow-up appointment have been more clearly described.[8,9]

Given these improvements in asthma practice, including evidence of improved performance on the HEDIS asthma medication measure,[10] and long-standing guidelines from the NHLBI regarding a step-wise approach to primary care asthma management,[1] it is possible that follow-up would be associated now with decreased subsequent asthma exacerbations. In this context, and given the substantial burden of asthma in children,[11,12] the Pediatric Quality Measures Program (PQMP) developed and tested a quality measure of 14-day follow-up after an asthma-related ED visit. The PQMP was created under the Children's Health Insurance Program Reauthorization Act and is funded through the Center for Medicare and Medicaid Services, overseen by the Agency for Healthcare Research and Quality. The PQMP was established to address gaps in assessing quality in pediatric care and led to the development of numerous pediatric quality measures,[13] including the one used in this study.

ED asthma visits represent significant burden for the health care system and are associated with increased costs, missed days of work and school.[14,15] Since clinical practice has evolved in the last few decades and there has been increased interest in markers of quality asthma care, our team reexamined the effect of follow-up after an ED asthma visit in a multistate analysis. Our aim was to reassess the relationship between follow-up in this setting and subsequent asthma-related ED revisits.

## METHODS

### DATA SOURCES

We used administration data from the California (CA) Medicaid claims 2014-16, the Vermont (VT) all-payer claims database (APCD) 2014-16, and the Massachusetts (MA) APCD 2013-15. APCDs are comprehensive databases that provide claims from most insurers (commercial, Medicaid, and Medicare), but do not include individuals covered by TRICARE, Veteran's Affairs, the Federal Employees Health Benefits Program, or some commercial self-pay insurance plans.[13,14] The Massachusetts and Vermont APCDs were developed in 2009 and have been used in peer-reviewed literature and for population-based reports on health.[13−17]

### STUDY POPULATION

Eligible patients were those aged 3 to 21 years with an asthma-related emergency department visit in the measurement year (2015 for CA and VT and 2014 for MA). Asthma-related visits were defined as having an asthma-specific *International Classification of Diseases (ICD) Ninth or 10th Revision* code (Table 1) in the ED claim in the primary or second diagnostic space.

### MAIN PREDICTOR

The main predictor was a follow-up visit that aligns with the NHLBI guidelines,[1] a visit to a primary care or asthma-specific subspecialty provider. The specific provider classifications that were included as qualifying follow-up visits were: Family Medicine, General Practice, Internal Medicine, Pediatrics, Pulmonology, and Allergy & Immunology.

### COVARIATES

To assess for variations in the main predictor, we examined associations with the following patient characteristics: average age during the evaluation year (categorized as 3-5, 6-11, 12-17, and 18+ years), gender, primary insurance type (Medicaid or commercial), and chronic disease status as defined by the Pediatric Medical Complexity Algorithm (PMCA), categorized as Nonchronic, Noncomplex chronic, and Complex chronic,[16,17] using, for the PMCA, 2 years of data (the evaluation year and 1 year of look-back) and excluding asthma conditions from the PMCA definition. We assessed differences in the main predictor by whether the patient had prior evidence of asthma, a yes/no variable, defined by the PQMP. This uses administrative claims to identify children who have utilized health care services in the prior year in a way that suggests that the child has an asthma diagnosis requiring ongoing care. Details of the PQMP approach for prior evidence of asthma have been published previously.[18,19] Briefly summarized, the definition includes: prior hospitalization for asthma, one or more ambulatory visits with a diagnosis of asthma or bronchitis, and/or at least one asthma-related prescription. The numbers of ambulatory visits and asthma-related prescriptions required for inclusion vary by patient age. Patients with a diagnosis of cystic fibrosis or emphysema were excluded.

### OUTCOME

Our outcome of interest was subsequent asthma-related ED revisits following the index ED visit. We examined the outcome as three binary indicators (any ED revisit within 60 days, 365 days, or through the end of available follow-up) and as a continuous indicator (number of ED revisits during follow-up/100 child-days). Revisits *within* the 14-day period following the index ED visit were not included in any of the outcome definitions.

### ANALYSIS

We used logistic regression models with the binary indicators of subsequent asthma-related ED revisits within 60 days and within 365 days of the index ED visit. We used Cox survival analysis for the outcome of time to the first subsequent asthma-related ED revisit within the available follow-up time and starting 14 days after the index ED visit. We used negative binomial regression models with an outcome of the number of subsequent asthma-related ED revisits during the follow-up period.

In each analysis, we adjusted the models for average age during the index year (measured continuously) and gender, chronic disease status, insurance type, and evidence of prior asthma, as specified above. We tested for significant interactions between evidence of prior asthma and primary or specialty care follow-up within 14 days of the index ED visit in each model. All models used cluster robust standard errors, to accomodate correlation at the zip code level. We calculated discrimination and calibration of the logistic models using C-statistic and Hosmer Lemeshow goodness of fit testing in the CA data.

We obtained predicted relationships for each adjusted analysis using Stata's post-estimation "margins" command.[20] This calculates a marginal (or average) rate by averaging predicted values for each category of the predictor, assuming it was in each of the categories, but using its covariate values for all the other variables to generate the predicted values.[20] We chose to use marginal rates because they have a more intuitive interpretation, and are more easily compared with the raw rates, than are $\beta$-coefficients derived from the regression model. To calculate the rate per 100 child-years we multiplied the marginal rates by 100.

Due to restrictions in data-sharing to protect patient confidentiality, we were not able to aggregate all state datasets in one location. Hence, we performed analyses for each state dataset separately and then used a fixed-effects meta-analysis to summarize the results of the individual state analyses. Because we were able to run exactly the same analysis code across all the state databases, this approach was as efficient as conducting an analysis on the individual level data while adjusting for state.[21] We used the Stata "metan" command with the "fixed" option for state to perform the meta-analyses.

As a sensitivity analysis, we included measures of social risk into the multivariable analysis of the CA data, as prior work has shown that social risk factors may be associated with subsequent acute care utilization.[22–25] Using patient 5-digit zip codes, we linked zip code-level social risk factors from the US American Community Survey (5-year file), as suggested in national guidelines.[26] We included: percentage of

**Table 2.** Association Between Follow-Up Within 14 Days of Asthma ED Visit and Patient Characteristics and States, Unadjusted

| Patient Characteristics | Number With an ED Visit, N (%) | Follow-Up Within 14 Days, N (%) | No follow-Up Within 14 Days, N (%) |
|---|---|---|---|
| All ED asthma visits | 90,267 (100) | 20,384 (22.6) | 69,883 (77.4) |
| Age group, years | | | |
| 3–5 | 22,498 (24.9) | 6291 (30.9) | 16,207 (23.2) |
| 6–11 | 32,664 (36.2) | 8019 (39.3) | 24,645 (35.3) |
| 12–17 | 21,642 (24.0) | 4505 (22.1) | 17,137 (24.5) |
| 18–21 | 13,463 (14.9) | 1569 (7.7) | 11,894 (17.0) |
| Gender | | | |
| Male | 51,305 (56.8) | 11,956 (58.7) | 39349 (56.3) |
| Female | 38,962 (43.2) | 8428 (41.3) | 30534 (43.7) |
| Insurance type | | | |
| Commercial | 3484 (3.9) | 1427 (7.0) | 2057 (2.9) |
| Medicaid | 86,783 (96.1) | 18,957 (93.0) | 67,826 (97.1) |
| PMCA* | | | |
| None | 59,503 (65.9) | 12,338 (60.5) | 47,165 (67.5) |
| Chronic, noncomplex | 17,362 (19.2) | 4347 (21.3) | 13,015 (18.6) |
| Complex chronic | 13,402(14.8) | 3699 (181) | 9703 (13.9) |
| Prior evidence of asthma** | | | |
| No prior asthma | 17,582 (19.5) | 2802 (13.7) | 14,780 (21.1) |
| Prior asthma | 72,685 (80.5) | 17,582 (86.3) | 55,103 (78.9) |
| State | | | |
| CA 2016 | 74,568 (82.6) | 15,407 (75.6) | 59,161 (84.7) |
| MA 2015 | 14,168 (15.7) | 4536 (22.3) | 9632 (13.8) |
| VT 2016 | 1531 (1.7) | 441 (2.2) | 1090 (1.6) |

ED indicates emergency department. All percentages are column percentages, except for the top row, which is a row percentage. All states are included in patient characteristics analyses.

*PMCA: Pediatric Medical Complexity Algorithm (Simon et al)[16,17] was used to determine chronic disease, which uses ICD9 and 10 definitions of chronic disease to create a categorical variable. Asthma was excluded from the PMCA algorithm for the purposes of this study.

**"Prior evidence of asthma" defined as prior claims-based utilization for asthma diagnoses in the past year, as published previously.[18,19]

**Table 3.** Association Between Follow-Up Within 14 Days of Asthma ED Visit and Patient Characteristics, Adjusted

| Patient Characteristics | Follow-Up Within 14 Days, Adjusted (%) | *P*-Value for Adjusted Model |
|---|---|---|
| All ED asthma visits | 22.2% (21.9–22.4) | NA |
| Age group, years | | |
| 3–5 | 30.8% (30.0–31.7) | Ref. |
| 6–11 | 23.7% (23.1–24.4) | <.001 |
| 12–17 | 19.9% (19.2–20.5) | <.001 |
| 18–21 | 11.0% (10.4–11.6) | <.001 |
| Gender | | |
| Male | 22.4% (21.9–22.9) | Ref. |
| Female | 22.5% (22.0–23.1) | .20 |
| Insurance type | | |
| Commercial | 43.7% (41.9–45.5) | Ref. |
| Medicaid | 21.7% (21.2–22.2) | .001 |
| PMCA* | | |
| None | 20.2% (19.7–20.7) | Ref. |
| Chronic, noncomplex | 25.7% (25.0–26.4) | <.001 |
| Complex chronic | 28.9% (28.0–29.7) | <.001 |
| Prior evidence of asthma** | | |
| No prior asthma | 14.7% (14.1–15.3) | Ref. |
| Prior asthma | 24.3% (23.8–24.9) | <.001 |

ED indicates emergency department. Assessed using negative binomial regression, clustered at the zip code level, followed by marginal estimation to provide adjusted percent. Adjusted for age category, gender, chronic condition indicator, insurance type, prior evidence of asthma.

*PMCA: Pediatric Medical Complexity Algorithm (Simon et al)[16,17] was used to determine chronic disease, which uses ICD9 and 10 definitions of chronic disease to create a categorical variable. Asthma was excluded from the PMCA algorithm for the purposes of this study.

**"Prior evidence of asthma" defined as prior claims-based utilization for asthma diagnoses in the past year, as published previously.[18,19]

adults with less than high school education; percentage of unemployed adults aged ≥16 years, percentage of households below the federal poverty line, and median household income. These variables have been validated as measures of social risk associated with poor health outcomes in adults and have been associated with increased health care utilization and readmissions in pediatrics.[22–25]

We used SAS version 9.4 (SAS Institute, Inc., Cary, NC) for data management. All other calculations used Stata 16 (Stata Corp, College Station, Tex). The University of California, San Francisco's institutional review board approved this study.

## RESULTS

Across the three states, there were 90,267 patients with an asthma-related emergency department index visit during the measurement year for the state. Of these, 93.2% (n = 84,170) had at least 365 days of follow-up data. Follow-up within 14 days with either a PCP or specialist occurred in only 22.6% (n = 20,384) of the index ED visits (Table 2). Of the follow-up visits, 70.9% were with a pediatrician, 17.0% with a family medicine physician, 9.2% with a general internal medicine doctor, and 3.0% with a pulmonologist or allergy/immunologist. In adjusted analyses, predictors associated with follow-up included younger age group, having commercial insurance, having a complex chronic condition, and having prior evidence of asthma (Table 3).

Patients with follow-up visits within 14 days had a lower frequency of having any subsequent asthma-related

**Table 4.** Relationship Between Follow-up Visit Within 14 Days After Asthma-Related ED Visit and Subsequent Asthma-Related ED Revisit, Adjusted

| | ED Revisit Within 60 Days, % (95% CI) | *P* Value | ED Revisit Within 365 Days, % (95% CI) | *P* Value |
|---|---|---|---|---|
| Follow-up visit status | | | | |
| No follow-up in 14 days | 6.4% (6.2–6.6) | ref | 28.3% (27.8–28.7) | ref |
| Follow-up in 14 days | 5.7% (5.3–6.0) | <.001 | 25.0% (24.4–25.7) | <.001 |
| Age group, years | | | | |
| 3–5 | 7.9% (7.5–8.3) | ref | 35.5% (34.8–36.2) | ref |
| 6–11 | 4.4% (4.2–4.7) | <.001 | 25.2% (24.7–25.8) | <0.001 |
| 12–17 | 4.6% (4.4–4.9) | <.001 | 22.4% (21.7–23.0) | <.001 |
| 18–21 | 7.7% (7.3–8.2) | .10 | 28.7% (27.9–29.6) | <.001 |
| Gender | | | | |
| Male | 6.4% (6.2–6.6) | ref | 27.9% (27.5–28.4) | ref |
| Female | 6.0% (5.7–6.2) | .93 | 27.9% (27.3–28.5) | .02 |
| Insurance status | | | | |
| Commercial | 3.0% (2.4–3.5) | ref | 15.7% (14.3–17.1) | ref |
| Medicaid | 6.4% (6.2–6.6) | <.001 | 28.3% (27.9–28.7) | <.001 |
| PMCA* | | | | |
| None | 6.0% (5.8–6.2) | ref | 27.1% (26.6–27.5) | ref |
| Chronic, noncomplex | 6.6% (6.2–7.0) | <.001 | 29.4% (28.7–30.1) | <.001 |
| Complex chronic | 6.9% (6.4–7.3) | <.001 | 27.8% (27.0–28.6) | <.001 |
| Prior evidence of asthma** | | | | |
| No prior asthma | 4.1% (3.8–4.3) | ref | 19.6% (19.1–20.2) | ref |
| Prior asthma | 7.1% (6.9–7.3) | <.001 | 30.5% (30.0–30.9) | <.001 |

ED indicates emergency department. Assessed using negative binomial regression, clustered at the zip code level, followed by marginal estimation to provide adjusted percent. Adjusted for age category, gender, chronic condition indicator, insurance type, prior evidence of asthma.

*PMCA: Pediatric Medical Complexity Algorithm (Simon et al)[16,17] was used to determine chronic disease, which uses ICD9 and 10 definitions of chronic disease to create a categorical variable. Asthma was excluded from the PMCA algorithm for the purposes of this study.

**"Prior evidence of asthma" defined as prior claims-based utilization for asthma diagnoses in the past year, as published previously.[18,19]

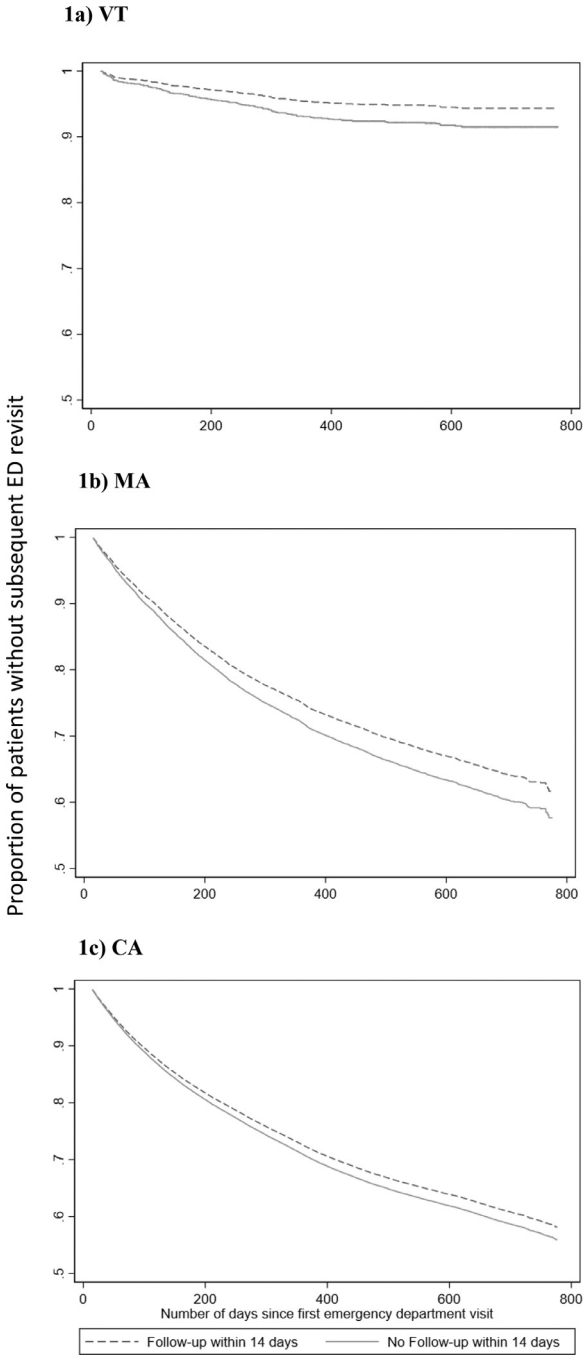


**Figure.** *Kaplan-Meier survival curves by state showing relationship between having a follow-up visit within 14 days after asthma-related ED visit and subsequent asthma-related ED revisit within 2 years after index visit.*

ED revisit compared to those without within 60 days (5.7% versus 6.4%, $P < .001$) and 365 days (25.0% versus 28.3%, $P < .001$; Table 4), and in the Cox survival analysis (HR = −0.085 (95% CI: −0.11 to −0.06), $P < .001$; Figure). In both adjusted and unadjusted analyses, patients with a follow-up visit within 14 days also had lower rates of subsequent asthma-related ED revisit over time (adjusted analysis: 66.7 revisits/100 child-years versus 77.3 revisits/100 child-years for those without a follow-up visit, $P < .001$; Table 5). We did not find any statistically significant interactions with having had prior evidence of asthma.

In sensitivity analyses, the inclusion of zip-code-level social risk factors did not change model calibration, minimally changed discrimination (Table 6) and did not change the direction of the relationship between follow-up and subsequent ED revisits: 30.1 versus 28.1% for revisits within a year ($P < .001$); 6.8% versus 6.2% for revisits within 60 days ($P = .02$).

## DISCUSSION

In this multistate analysis of children and youth with ED visits for asthma, we found an association between 14-day follow-up visits and decreased subsequent asthma-related ED revisits. This finding was consistent at both long- and short-term time points, with a larger effect size in the assessment of association with repeated subsequent utilization. In addition, almost all follow-up occurred with primary care physicians, primarily pediatricians. Those who had follow-up were more likely to have evidence of asthma prior to the ED visit.

Previously published work found either a paradoxical relationship, with follow-up after an ED visit associated with increased subsequent acute utilization, or found no protective effect of the follow-up visit.[4–7] However, primary care asthma management has changed over the last years to be more consistent with the NHLBI asthma stepwise approach to using daily medications to reduce the likelihood of asthma exacerbations and asthma-related ED use or hospitalization.[27] Over the last few decades, key clinical activities for primary care providers have been broadly disseminated and described.[8,9,28] In addition, there has been better provider adherence to the NHLBI recommendations to use daily inhaled corticosteroids for children with persistent asthma to prevent asthma exacerbations, and resulting ED visits. For example, in 2002, the National Committee on Quality Assurance developed a HEDIS measure to assess the frequency of the prescription of a daily inhaled corticosteroid for patients with persistent asthma. However, after 14 years, the measure was retired in 2016 due to the observation that "HEDIS performance rates have been consistently high for commercial and Medicaid plans over the past several years."[10] The results of our study suggest that these improvements in primary care delivery are associated with improved prevention of subsequent ED revisits.

The size of the associated decreases in ED use were modest, with a "number needed to treat" of 30 follow-up visits needed to prevent one subsequent ED revisit within a year and 143 to prevent one within 60 days. However, taken over a large population, the decreased revisits represent substantial savings and improved quality of life for patients with asthma and their families. Follow-up visits were associated with 10.6 fewer ED revisits/100 child-years. In 2016, there were 674,145 ED visits for asthma for children 1 to 17 years nationally. If follow-up was in place for all visits, this translates into a potential ~72,000

**Table 5.** Relationship Between Follow-Up After Asthma-Related ED Visit and Repeated Subsequent Asthma-Related ED Revisits

| | Subsequent ED Revisits/ 100 Child-Years, Unadjusted | Subsequent ED Revisits/ 100 Child-Years, Adjusted | *P*-Value for Adjusted Model |
|---|---|---|---|
| Follow-up visit status | | | |
| No follow-up in 14 days | 78.2 (76.4–79.9) | 77.3 (75.6–79.0) | Ref. |
| Follow-up in 14 days | 67.1 (64.9–69.2) | 66.7 (64.6–68.8) | <.001 |
| Age group, years | | | |
| 3–5 | 87.7 (85.3–90.0) | 100.8 (98.0–103.6) | Ref. |
| 6–11 | 63.7 (62.0–65.5) | 60.9 (59.2–62.6) | <.001 |
| 12–17 | 59.7 (57.7–61.7) | 58.3 (56.3–60.2) | <.001 |
| 18–21 | 93.2 (89.1–97.3) | 91.4 (87.7–95.1) | <.001 |
| Gender | | | |
| Male | 77.5 (75.8–79.2) | 76.2 (74.5–77.8) | Ref. |
| Female | 76.7 (74.6–78.9) | 75.0 (73.0–77.0) | .10 |
| Insurance status | | | |
| Commercial | 43.5 (39.1–47.9) | 44.7 (40.3–49.1) | Ref. |
| Medicaid | 77.9 (76.3–79.4) | 76.8 (75.2–78.3) | <.001 |
| PMCA* | | | |
| None | 72.2 (70.6–73.8) | 73.8 (72.2–75.4) | Ref. |
| Chronic, noncomplex | 78.8 (76.3–81.3) | 80.8 (78.3–83.3) | <.001 |
| Complex chronic | 83.3 (79.6–86.9) | 75.1 (71.9–78.3) | <.001 |
| Prior evidence of asthma** | | | |
| No prior asthma | 54.0 (52.3–55.7) | 49.0 (47.5–50.6) | Ref. |
| Prior asthma | 84.4 (82.6–86.2) | 85.7 (83.9–87.5) | <.001 |

ED indicates emergency department. Assessed using negative binomial regression, clustered at the zip code level, followed by marginal estimation to provide adjusted mean. Adjusted for age category, gender, chronic condition indicator, insurance type, prior evidence of asthma.

*PMCA: Pediatric Medical Complexity Algorithm (Simon et al)[16,17] was used to determine chronic disease, which uses ICD9 and 10 definitions of chronic disease to create a categorical variable. Asthma was excluded from the PMCA algorithm for the purposes of this study.

**"Prior evidence of asthma" defined as prior claims-based utilization for asthma diagnoses in the past year, as published previously.[18,19]

subsequent revisits prevented. Charges for ED revisit (not those leading to hospitalizations) for 0 to 19 year olds were estimated to be $1,108 to $1,263 in 2006–2008,[29] translating into a savings of at least $8.6 million if calculated across subsequent visits prevented. Our findings suggest that those with repeated asthma exacerbations will likely see particular benefit to having follow-up after an ED visit. However, these benefits need to be weighed against the "costs" of a follow-up visit, including potential lost time from school or work. Future research could explore how telehealth visits, in light of meaningful uptake during the COVID-19 pandemic, might be used for follow-up and whether telehealth would be associated with similar benefits, while decreasing caregiver and patient burden.

The "mechanism of action" through which follow-up visits might decrease subsequent use deserves some discussion. Though social risk has been shown to be associated with increased utilization in pediatrics, we did not find that inclusion of zip-code-level social risk factors changed our findings substantially. Our hypothesis was that social risk would serve as a confounder to the relationship between follow-up visits and subsequent ED visits, with those with higher SES having both better access to care (resulting in the 14-day visit) as well as decreased risk of a repeat ED visit through better access to housing and transportation, higher health literacy, and other social determinants of health. The limited changes to the results suggests that primary care visits protect against subsequent revisits

**Table 6.** Calibration and Discrimination for Logistic Models for Events Within Time Period After Initial ED Visit

| Multivariable Logistic Regression for: | Discrimination • C-Statistic | Calibration • Hosmer Lemeshow Goodness of Fit |
|---|---|---|
| Follow-up visit within 14 days (Table 4) | C-statistic: 0.62 | *P* = .003. Observed versus expected probabilities across deciles very similar, with <0.006 absolute difference between any given decile. |
| Follow-up visit within 14 days, including measures of social risk | C-statistic: 0.62 | *P* = .02. Observed versus expected probabilities across deciles very similar, with <0.015 absolute difference between any given decile. |
| Repeat ED visit within 60 days (Table 5) | C-statistic: 0.58 | *P* = .15. Observed versus expected probabilities across deciles very similar, with <0.002 absolute difference between any given decile. |
| Repeat ED visit within 60 days, including measures of social risk | C-statistic: 0.58 | *P* = .03. Observed versus expected probabilities across deciles very similar, with <0.007 absolute difference between any given decile. |
| Repeat ED visit within 365 days (Table 5) | C-statistic: 0.58 | *P* < .001. Observed versus expected probabilities across deciles very similar, with <0.018 absolute difference between any given decile. |
| Repeat ED visit within 365 days, including measures of social risk | C-statistic: 0.58 | *P* = .003. Observed versus expected probabilities across deciles very similar, with <0.015 absolute difference between any given decile. |

ED indicates emergency department.

through direct delivery of health care services and access to care rather than mainly serving as a marker for higher socioeconomic status.

Other potential mechanisms through which the follow-up visit may have an effect include: the care delivered during the visit itself, and the broader effect of adequate access to care. We acknowledge that a primary care follow-up visit may not necessarily be important or sufficient; rather what is likely important is the content and conduct of the visit. In an analysis of characteristics of successful post-ED asthma visit interventions, Schatz et al note that, "An effective visit includes addressing multiple aspects of asthma care, including educational, environmental, pharmacologic, and psychosocial factors."[9] Future study with more clinical detail could describe these components of a primary care follow-up visit and potentially to identify which component may be most crucial. Follow-up at 14 days may indicate adequate access to care, as the access would facilitate the follow-up within a short time period. This suggests that the relationship with primary care may be a driver in decreased utilization, potentially through the mechanism of improved monitoring and control of asthma symptoms, which is associated with better outcomes,[30–32] along with the isolated occurrence of the 14-day follow-up appointment.

Our findings indicate an opportunity for improvement. Follow-up visits only occurred after 22.6% of visits and were almost half as frequent in the Medicaid population compared to those with commercial insurance. Improving this number may require complex solutions, since it likely requires action not only during the discharge process in the ED, but further upstream, in establishing primary care relationships and access.

The study has a number of limitations. Because we used an observational design, we are not able to attribute causality to the association. Our findings warrant further research to test interventions to support follow-up and primary care accessibility. Our analyses utilized administrative claims, which may under-identify patients with asthma, and are not able to capture differences in severity of asthma. However, potential selection bias (that patients with more severe asthma would be more likely to have follow-up) would have biased the results towards finding no protective effect of follow-up or a paradoxical effect. Thus, this limitation may have biased our findings towards the null. The administrative claims are not able to assess the quality of the follow-up visit. It is possible that some follow-up visits were more effective than others, and we were not able to describe those differences. We did not have full data on race and ethnicity, so were not able to conduct analyses by race or ethnicity. While a physiological difference by race or ethnicity is unlikely, structural racism and other social determinants of health may play a role in differential outcomes by race or ethnicity in the relationships assessed, and may be a focus of additional research.

## CONCLUSIONS

Follow-up visits after an asthma-related ED visits, in line with NHLBI guidelines, were associated with decreased subsequent asthma-related ED revisits, but occurred for fewer than a quarter of children and adolescents with an index ED visit. More robust systems of care to facilitate these types of follow-up visits can potentially improve asthma outcomes.

## ACKNOWLEDGMENTS

This project was supported by grants U18HS025297 and U18HS020518 from the Agency for Healthcare Research and Quality (AHRQ). The analyses, conclusions, and recommendations from the Vermont Health Care Uniform Reporting and Evaluation System (VHCURES) data are solely those of the study authors and are not necessarily those of the Green Mountain Care Board (GMCB).

The views expressed in this article are those of the authors, and no official endorsement by the Agency for Healthcare Research and Quality (AHRQ), the Centers for Medicare and Medicaid Services (CMS), or the Department of Health and Human Services (DHHS) is intended or should be inferred.

This article is published as part of a supplement sponsored by the US Department of Health and Human Services, the Centers for Medicare and Medicaid Services, and the Agency for Healthcare Research and Quality.

## REFERENCES

1. Expert Panel Report 3 (EPR-3): guidelines for the diagnosis and management of asthma-summary report 2007. *J Allergy Clin Immunol*. 2007;120(5 Suppl):S94–138.
2. Global Initiative for Asthma (GINA). The global strategy for asthma management and prevention. Available at: https://ginasthma.org/gina-reports/. Published 2020. Accessed November 30, 2020.
3. Lougheed MD, Leniere C, Ducharme FM, et al. Canadian Thoracic Society 2012 guideline update: diagnosis and management of asthma in preschoolers, children and adults: executive summary. *Can Respir J*. 2012;19:e81–e88.
4. Cabana MD, Bruckman D, Bratton SL, et al. Association between outpatient follow-up and pediatric emergency department asthma visits. *J Asthma*. 2003;40:741–749.
5. Liberman DB, Shelef DQ, He J, et al. Low rates of follow-up with primary care providers after pediatric emergency department visits for respiratory tract illnesses. *Pediatr Emerg Care*. 2012;28:956–961.
6. Baren JM, Boudreaux ED, Brenner BE, et al. Randomized controlled trial of emergency department interventions to improve primary care follow-up for patients with acute asthma. *Chest*. 2006;129:257–265.
7. Zorc JJ, Scarfone RJ, Li Y, et al. Scheduled follow-up after a pediatric emergency department visit for asthma: a randomized trial. *Pediatrics*. 2003;111:495–502.
8. Cabana MD, Slish KK, Evans D, et al. Impact of physician asthma care education on patient outcomes. *Pediatrics*. 2006;117:2149–2157.
9. Schatz M, Rachelefsky G, Krishnan JA. Follow-up after acute asthma episodes: what improves future outcomes? *J Emerg Med*. 2009;37(2 Suppl):S42–S50.
10. Assurance NCfQ. HEDIS 2016 public comment now open; Posted February 19, 2015. Available at: https://blog.ncqa.org/hedis-2016-public-comment-now-open/. Published 2015. Accessed January 24, 2021.
11. Perry R, Braileanu G, Palmer T, et al. The economic burden of pediatric asthma in the United States: literature review of current evidence. *PharmacoEconomics*. 2019;37:155–167.
12. Akinbami LJ, Simon AE, Rossen LM. Changing trends in asthma prevalence among children. *Pediatrics*. 2016;137:1–7. https://doi.org/10.1542/peds.2015-2354.

13. Mistry KB, Chesley F, Llanos K, et al. Advancing children's health care and outcomes through the pediatric quality measures program. *Acad Pediatr*. 2014;14(5, Supplement):S19–S26.
14. Sullivan PW, Ghushchyan V, Navaratnam P, et al. The national cost of asthma among school-aged children in the United States. *Ann Allergy Asthma Immunol*. 2017;119:246–252. e241.
15. Sullivan PW, Ghushchyan V, Navaratnam P, et al. The national burden of poorly controlled asthma, school absence and parental work loss among school-aged children in the United States. *J Asthma*. 2018;55:659–667.
16. Simon TD, Cawthon ML, Stanford S, et al. Pediatric medical complexity algorithm: a new method to stratify children by medical complexity. *Pediatrics*. 2014;133:e1647–e1654.
17. Simon TD, Haaland W, Hawley K, et al. Development and validation of the Pediatric Medical Complexity Algorithm (PMCA) version 3.0. *Acad Pediatr*. 2018;18:577–580.
18. Harder VS, Shaw JS, McCulloch CE, et al. Statewide asthma learning collaborative participation and asthma-related emergency department use. *Pediatrics*. 2020;146:e20200213. https://doi.org/10.1542/peds.2020-0213.
19. Bardach NS, Neel C, Kleinman LC, et al. Depression, anxiety, and emergency department use for asthma. *Pediatrics*. 2019;144:e20190856. https://doi.org/10.1542/peds.2019-0856.
20. Norton EC, Miller MM, Kleinman LC. Computing adjusted risk ratios and risk differences in Stata. *Stata J*. 2013;13:492–509.
21. Lin DY, Zeng D. On the relative efficiency of using summary statistics versus individual-level data in meta-analysis. *Biometrika*. 2010;97:321–332.
22. Bird CE, Seeman T, Escarce JJ, et al. Neighbourhood socioeconomic status and biological 'wear and tear' in a nationally representative sample of US adults. *J Epidemiol Community Health*. 2010;64:860–865.
23. Beck AF, Huang B, Wheeler K, et al. The child opportunity index and disparities in pediatric asthma hospitalizations across one Ohio Metropolitan area, 2011-2013. *J Pediatr*. 2017;190:200–206. e201.
24. Baltrus P, Xu J, Immergluck L, et al. Individual and county level predictors of asthma related emergency department visits among children on Medicaid: a multilevel approach. *J Asthma*. 2017;54:53–61.
25. Auger KA, Kahn RS, Simmons JM, et al. Using address information to identify hardships reported by families of children hospitalized with asthma. *Acad Pediatr*. 2017;17:79–87.
26. Second Report to Congress on Social Risk Factors and Performance in Medicare's Value-Based Purchasing Program. U.S. Department of Health and Human Services. Available at: https://aspe.hhs.gov/pdf-report/second-impact-report-to-congress#:~:text=As%20required%20by%20the%20IMPACT,on%20providers%20serving%20socially%20at%2D. Published 2020. Accessed December 2, 2021.
27. Rust G, Zhang S, McRoy L, Pisu M. Potential savings from increasing adherence to inhaled corticosteroid therapy in Medicaid-enrolled children. *Am J Manag Care*. 2015;21:173–180.
28. Williams SG, Schmidt DK, Redd SC, et al. Key clinical activities for quality asthma care. Recommendations of the National Asthma Education and Prevention Program. *MMWR Recomm Rep*. 2003;52(RR-6):1–8.
29. Wang T, Srebotnjak T, Brownell J, et al. Emergency department charges for asthma-related outpatient visits by insurance status. *J Health Care Poor Underserved*. 2014;25:396–405.
30. NIH. National Institutes of Health, National Heart, Lung, and Blood Institute. Guidelines implementation panel report for: expert panel report 3: guidelines for the diagnosis and management of asthma: partners putting guidelines into action. *NIH Publication Number 09-6147*. U.S. Department of Health and Human Services; 2008.
31. NHLBI. Guidelines for the diagnosis and management of asthma 2007 (EPR-3). National Heart, Lung and Blood Institute. Available at: https://www.nhlbi.nih.gov/health-topics/guidelines-for-diagnosis-management-of-asthma. Published 2007. Accessed October 18, 2021.
32. NHLBI. 2020 Focused updates to the asthma management guidelines: a report from the National Asthma Education and Prevention Program Coordinating Committee Expert Panel Working Group. Available at: https://www.nhlbi.nih.gov/health-topics/all-publications-and-resources/2020-focused-updates-asthma-management-guidelines. Published 2020. Accessed October 18, 2021.