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A Multicenter Observational Study of US Adults with Acute Asthma: Who Are the Frequent Users of the Emergency Department?

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What is already known about this topic? Prior studies demonstrated that many patients frequently visited the emergency department (ED) for acute asthma. Despite the substantial burden of these asthma-related ED visits, there have been no recent multicenter efforts to characterize this high-risk population.

What does this article add to our knowledge? This multicenter study found that half of the patients had 2:1 ED visits for acute asthma in the past year and that only a small subset of these frequent users received currently recommended long-term control therapy.

How does this study impact current management guidelines? Knowledge translation initiatives and quality improvement efforts in chronic asthma management are needed to decrease the observed care gap (and individual and/or societal burden) of those who frequently use the ED for their acute asthma care.

Abbreviations used

ED Emergency department *ICU* Intensive care unit *IQR* Interquartile range

OR Odds ratio

PEF Peak expiratory flow

BACKGROUND: Despite the substantial burden of asthma-related emergency department (ED) visits, there have been no recent multicenter efforts to characterize this high-risk population.

OBJECTIVE: We aimed to characterize patients with asthma according to their frequency of ED visits and to identify factors associated with frequent ED visits.

METHODS: A multicenter chart review study of 48 EDs across 23 US states. We identified ED patients ages 18 to 54 years with acute asthma during 2011 and 2012. Primary outcome was frequency of ED visits for acute asthma in the past year, excluding the index ED visit.

RESULTS: Of the 1890 enrolled patients, 863 patients (46%) had 1 or more (frequent) ED visits in the past year. Specifically, 28% had 1 to 2 visits, 11% had 3 to 5 visits, and 7% had 6 or more visits. Among frequent ED users, guideline-recommended management was suboptimal. For example, of patients with 6 or more ED visits, 85% lacked evidence of prior evaluation by an asthma specialist, and 43% were not treated with inhaled corticosteroids. In a multivariable model, significant predictors of frequent ED visits were public insurance, no insurance, and markers for chronic asthma severity (all $P < .05$). Stronger associations were found among those with a higher frequency of asthma-related ED visits (eg, 6 or more ED visits). **CONCLUSION:** This multicenter study of US adults with acute asthma demonstrated many frequent ED users and suboptimal preventive management in this high-risk population. Future reductions in asthma morbidity and associated health care utilization will require continued efforts to bridge these major gaps in asthma care.

Key words: Acute asthma; Emergency department; Epidemiology exacerbation; Health care utilization; Racial disparity; Socioeconomic status

Asthma prevalence remains at historically high levels, which affected 26 million Americans in 2011.¹ Asthma continues to cause a substantial health burden, with an estimated economic cost of \$56 billion annually.² Acute asthma contributes to a significant proportion of this burden and accounts for 440,000 hospitalizations and 1.8 million emergency department (ED) visits annually.³ Asthma-related ED visits offer an important measure of the morbidity associated with asthma.⁴ Because 80% to 90% of ED patients with acute asthma are discharged home,⁵ these patients provide a unique perspective of acute morbidity, a perspective that complements hospitalization and mortality statistics.⁴ In addition, because most ED visits for acute asthma are theoretically preventable through high-quality longitudinal management,⁶ multiple ED visits reflect failure of less costly and more prevention-oriented outpatient care.⁷ Our previous multicenter study through the late 1990s found that 73% of ED patients with acute asthma reported at least 1 prior ED visit for acute asthma in the previous year (ie, they had “frequent” ED visits).⁷ By contrast, between 2009 and 2010, analysis of claims data from California and Florida found that 26% of patients were frequent ED users.⁵ Although the decreasing incidence of frequent ED visits is encouraging, inferences from the claims data are somewhat limited due to potential error in data collection and coding, and inevitable questions about generalizability (ie, 2 states). Despite the substantial burden of asthma-related ED visits, there have been no recent multicenter efforts to characterize this high-risk population. To address this knowledge gap, we conducted a multicenter study in 48 US EDs to characterize the patients with acute asthma who frequently visit the ED and to identify factors associated with frequent ED visits in this high-risk population.

METHODS

Study design and setting

We performed a multicenter chart review study to characterize adult ED patients with acute asthma as part of the Multicenter Airway Research Collaboration. This study was coordinated by the Emergency Medicine Network, a collaboration with >225 participating EDs.⁸ We recruited EDs by inviting Emergency Medicine Network sites that had participated in the earlier Multicenter Airway Research Collaboration studies that evaluated patients with frequent ED visits for asthma during 1996 to 2001.⁷ A total of 48 academic and community EDs across 23 US states completed the study (see Table E1 and Figure E1 in this article’s Online Repository at www.jaci-inpractice.org). All the patients were managed at the discretion of the treating physician. The institutional review board of each participating center approved the study.

Selection of participants

By using the International Classification of Diseases, Ninth Revision, Clinical Modification code 493.xx,⁹ each site identified all visits with a primary ED or hospital discharge diagnosis of asthma during a 12-month period, between January 1, 2011, to December 31, 2012 (ie, they used a 24-month window from which to select the 12-month study period). Inclusion criteria were ED visits made by adult patients ages 18 to 54 years and a history of physician-diagnosed asthma before the index ED visit. We excluded the following: (1) ED visits made by patients with a history of physician-diagnosed chronic obstructive pulmonary disease, chronic bronchitis, or emphysema; (2) transfer visits; (3) repeated visits during the 12-month study period by the same individual; or (4) visits not prompted largely by acute asthma in the judgment of the site investigators. In the case of repeated visits, we only included the first randomly sampled ED visit and defined it as the index ED visit. These criteria were the same as in our earlier research on this topic.⁷

Methods of measurement

Onsite chart abstractors reviewed 40 ED charts randomly selected by the Emergency Medicine Network Coordinating Center at Massachusetts General Hospital. Two hospitals each examined an additional 40 randomly selected charts to obtain a total of 2000 charts. All the reviewers were trained with a 1-hour lecture and then the abstractors completed 2 practice charts, which were evaluated with a “criterion standard.” If a reviewer’s accuracy was <80% per chart, then the reviewer was retrained. Data abstraction was performed with a standardized form and included patients’ demographics (age, sex, and race and/or ethnicity), primary insurance type, median household income, primary care physician status, asthma history, specialty care status in the 12 months before the index ED visit, current asthma medications, details of the current asthma exacerbation, asthma management in ED or

at discharge, and ED disposition. Primary insurance types were categorized into private sources, public insurance (eg, Medicaid, Medicare), self-pay, and other. Median household income was estimated by using home ZIP codes.¹⁰ Specialty care was defined as outpatient asthma care by an allergy/immunologist, pulmonologist, or another physician who focus on asthma care (eg, a general internist who is director of the local asthma center).

Outcome measurements

The outcome measurement of interest was the frequency of ED visits for acute asthma in the past year, excluding the index ED visit. To measure this outcome, the number of ED visits with acute asthma during the preceding 365 days from the index ED visit was counted for each patient.

Data analysis

We classified patients into 4 ED utilization groups based on the previous literature⁷: no ED visits (ie, index visit only), 1 to 2 prior ED visits, 3 to 5 prior ED visits, and 6 or more ED visits in the past year. First, unadjusted associations between patient characteristics and frequency of ED visits for acute asthma were tested with using χ^2 , Fisher exact, or Kruskal-Wallis tests. Second, multivariable multinomial logistic regression models were fit to examine independent associations between patient characteristics and frequency of ED visits, with the no prior ED visit group as the reference. A set of variables were chosen based on *a priori* knowledge and potential clinical significance.^{5,7,11,12}

In a sensitivity analysis, we also constructed a negative binomial regression model. This model has the advantages that there is no need to define arbitrary cutoff points of the ED utilization and that the model appropriately accounts for statistical overdispersion.^{13,14} We also used a generalized estimating equation to account for patient clustering within the EDs. All tests were 2tailed, and $P < .05$ was regarded as statistically significant. All analyses were performed with SAS 9.3 (SAS Institute, Cary, NC).

RESULTS

We created a cohort of 2000 ED patients with acute asthma. Participating EDs had a median annual visit volume of 77,217 and a median of 679 ED visits for acute asthma per site. Most EDs were affiliated with an emergency medicine residency program in an urban setting. Of the 2000 patients enrolled, 1890 patients (95%) had data on the frequency of ED visits in the past year and were included in the current analysis. The analytic and nonanalytic cohorts were similar in their demographics, asthma history, current asthma medications, and ED course (all $P > .05$) (data not shown).

ED visits for acute asthma

Of the 1890 patients in the analytic cohort, 1027 (54%) had no prior ED visits for acute asthma, whereas 863 patients (46%) had at least 1 prior ED visit in the past year. Specifically, 538 patients (28%) had 1 to 2 visits, 199 patients (11%) had 3 to 5 visits, and 126 patients (7%) had 6 or more visits in the past year. The numbers of ED visits for acute asthma during the past year according to the frequency groups are shown in Figure 1. Patients with 1 to 2 ED visits accounted for 24%, those with 3 to 5 visits for 26%, and those with 6 or more visits for 50% of total ED visits in the past year.

Patient characteristics and ED course

Patient characteristics differed across the ED visit frequency groups (Table I). Several demographic characteristics, such as older age, male sex, and non-Hispanic black race, were associated with a higher frequency of ED visits with acute asthma (all $P < .05$). Similarly, markers of socioeconomic status, such as public insurance, no insurance, and lower household income, also were associated with a higher frequency of ED visits (all $P < .01$). In addition, patients with a higher frequency of ED visits were more likely to have a history of hospitalization, intubation, and systemic corticosteroid treatment for asthma, and to have been seen by an asthma specialist (all $P < .001$); they also were more likely to have been on oral corticosteroids and long-term control medications (all $P < .001$).

However, the proportion of patients who had been seen by an asthma specialist and who had used these long-term control medications were quite low across the frequency groups. For example, of patients with 6 or more ED visits, only 15% had evidence in the chart that they had been seen by specialists. Likewise, chart review (including all health system associated testing) showed that approximately 10% had undergone allergy testing (eg, specific IgE, skin prick testing) in the past year. Similarly, more than 40% of this population was not treated with inhaled corticosteroids.

Acute asthma presentation and the ED course by ED visit frequency are summarized in Table II. Although the vital signs at ED presentation were statistically different across the ED visit frequency groups, there were no clinically important differences. In contrast, ED management differed across

the frequency groups. Patients with a higher frequency of ED visits were more likely to receive systemic corticosteroids, intravenous magnesium, and mechanical ventilation (including invasive and noninvasive ventilation) in the ED (all $P < .05$). Likewise, these patients with a higher frequency of ED visits had a higher risk of hospitalization ($P < .001$).

Predictors of frequent ED visits with acute asthma

To examine the independent predictors of higher frequency of ED visits for acute asthma, multinomial logistic regression modeling was performed (Table III). Although race and/or ethnicity, estimated household income, and having a primary care physician were not significant, insurance status remained significant as an independent predictor of a higher frequency of ED visits across the frequency groups. The associations became stronger when we studied an outcome based on a higher frequency of ED visits. For instance, public insurance (odds ratio [95% CI, 1.19-3.45]; $P .01$) and no insurance (odds ratio 2.13 [95% CI, 1.16-3.92]; $P .02$) were independently associated with 6 or more ED visits. Similarly, markers of chronic asthma severity (eg, history of hospitalization and current use of inhaled corticosteroids) also were associated with a higher frequency of ED visits (all $P < .001$). In the sensitivity analysis by using negative binomial modeling, the multivariable results did not materially change (see Table E2 in this article's Online Repository at www.jaci-inpractice.org).

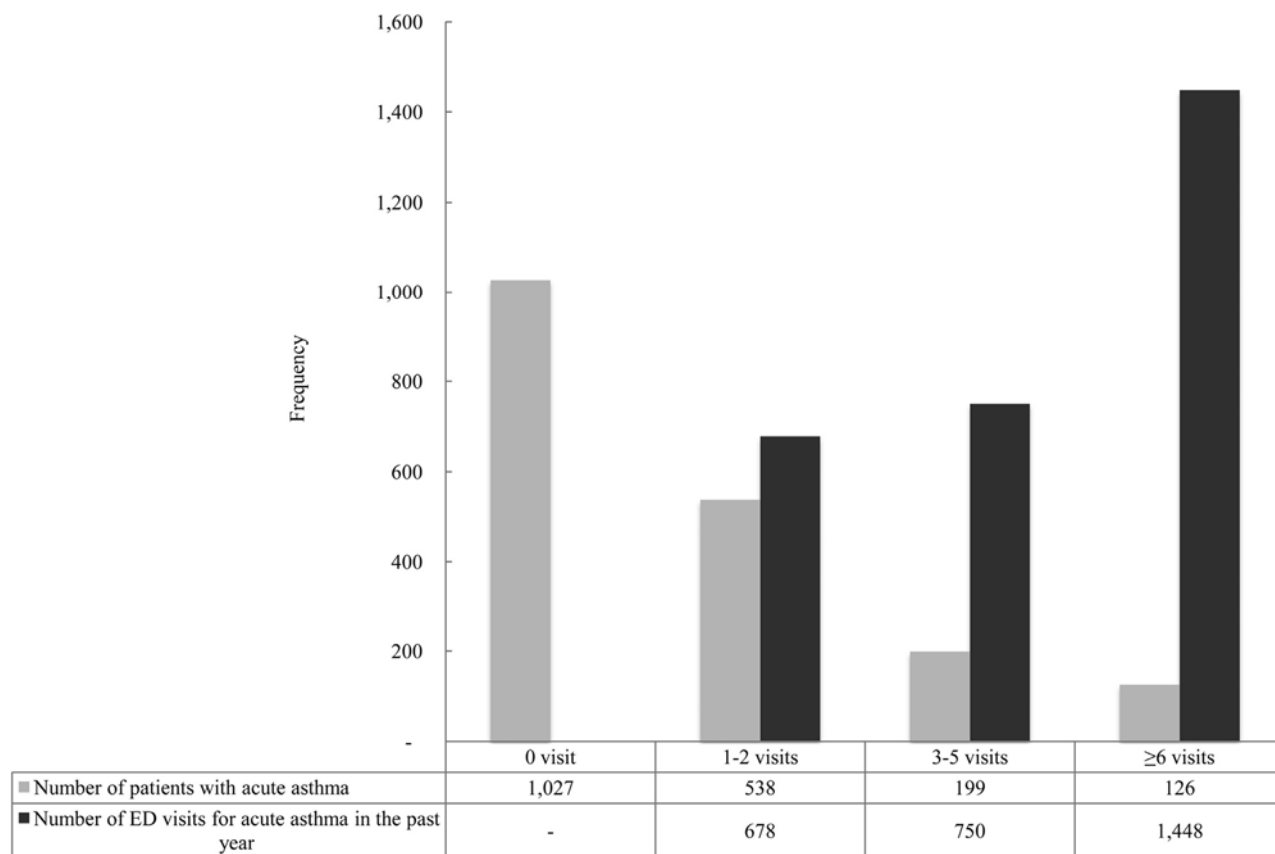


FIGURE 1. The numbers of patients with asthma and ED visits for asthma according to frequency of asthma-related ED visits.

DISCUSSION

In this study of 1890 adults who presented to 48 US EDs with acute asthma, we found that almost half had at least 1 prior asthma-related ED visit in the past year. We also found that only a small subset of these frequent ED users received outpatient management by asthma specialists and guideline-recommended long-term control management. Indeed, of patients with 6 or more ED visits, only 15% had been seen by specialists, and 10% had undergone allergy testing in the past year. Patients with public insurance or no insurance, and higher chronic asthma severity were more likely to have a higher frequency of ED visits. By contrast, we found no significant association between having a primary care physician and ED visit frequency for acute asthma.

Decrease in frequent ED users for acute asthma

Previous studies through the 1990s reported a large burden of patients with frequent ED visits for acute asthma.^{7,15} Indeed, the proportion of frequent ED users was 73% in our previous multicenter prospective study (n=3151)⁷ and 82% in a single-center cross-sectional study in New York City (n=375).¹⁵ By contrast, studies through the 2000s reported a lower burden of patients with frequent ED visits.¹¹ The proportion of frequent ED users was 33% in a telephone survey in southern Pennsylvania (30% response rate, which yielded n=1799),¹¹ and 26% in the retrospective analysis of administrative state databases from California and Florida (n=86,224).⁵ Interestingly, in our current study of patients who visited the ED for acute asthma between 2011 and 2012, the proportion of frequent ED users was 46%, which is higher than the studies in the 2000s. The reasons for this discrepancy are likely multifactorial. Potential explanations include differences in study design, inclusion criteria, and methods of data collection. Alternatively, the population in our study mainly consisted of urban teaching hospitals, and thereby resulted in disproportionately more patients who were sicker compared with the more community-based studies in the 2000s.^{5,11} Nevertheless, the proportion of frequent ED users in the current study was substantially lower (46% vs 73%) compared with our previous multicenter study during 1997 to 2001, in which the 48 sites in the current study were nested. Although the observed decrease might be due to differences in study design (ie, patient interview in our previous study vs chart review in the current study) the decrease also could reflect a true decrease in asthma severity and incidence of acute asthma over the 16-year period.

Ongoing large burden of frequent ED users for acute asthma

Although the observed decrease in frequent ED users for acute asthma is a promising possibility, the burden of the frequent users remains substantial. Indeed, approximately half of patients still are frequent ED users, which reflects the failure of current measures to manage these patients. In addition, we also were struck by the findings that only a small subset of these patients received optimal long-term control treatment and outpatient management by asthma specialists, both of which are recommended by the 2007 National Institutes of Health guidelines.⁶ Parallel to our findings, results of studies reported underuse of long-term control medications, asthma education, and outpatient care by specialists¹⁶⁻²⁰ as well as suboptimal coordination of care between EDs and asthma centers.²¹ Analysis of these data collectively indicates that quality improvement efforts in longitudinal (chronic asthma) management should be the priority areas of guideline dissemination and adoption initiatives. The observed decrease in frequent ED users supports prior optimism that asthma-related ED visits can be prevented and the burden reduced. The large remaining burden, however, underscores the importance of continued preventive efforts for this high-risk population.

TABLE I. Characteristics of patients with asthma according to frequency of asthma-related ED visits in the past 12 months

Patient characteristics	No ED visit (n = 127 [54%])	1-2 ED visits (n = 538 [28%])	3-5 ED visits (n = 199 [11%])	≥6 ED visits (n = 126 [7%])	P value
Demographics					
Age (y), median (IQR)	34 (25-44)	33 (25-45)	36 (27-47)	40 (29-47)	<.001
Male sex (%)	38	39	45	57	<.001
Race and/or ethnicity (%)*					.02
Non-Hispanic white	21	18	14	15	
Non-Hispanic black	49	51	61	62	
Hispanic ethnicity	20	20	15	17	
Others	4	3	3	1	
Current smoker (%)	33	31	34	36	.69
Body mass index, median (IQR)†	30 (26-37)	30 (25-37)	29 (25-35)	28 (24-34)	.39
Had a primary care physician (%)	58	60	62	61	.72
Health insurance (%)					<.001
Private	37	26	27	22	
Public	35	43	46	46	
No insurance	24	28	23	32	

Median household income (\$), median (IQR)	36,159 (27,280-51,372)	34,014 (26,371-49,878)	32,846 (25,886-45,653)	30,309 (25,756-46,661)	.009
Chronic asthma factors (%)					
Ever admitted for asthma	21	46	56	69	<.001
Ever intubated for asthma	7	15	20	31	<.001
Ever used systemic corticosteroids	35	72	85	91	<.001
Seen by asthma specialist in past 12 mo	5	9	19	15	<.001
Total IgE checked in past 12 mo	1	3	5	8	<.001
Allergen-specific IgE checked in past 12 mo	<1	1	3	2	.02
Skin prick testing checked in past 12 mo	<1	1	1	0	.49
Current asthma medications (%)					
Current use of oral corticosteroids	8	17	18	27	<.001
Current use of inhaled corticosteroids	27	43	53	57	<.001
Current use of long-acting β -agonist	17	30	37	42	<.001
Current use of leukotriene modifiers	7	14	18	25	<.001
Current use of omalizumab	<1	0	1	1	.23

IQR, Interquartile range.

*Percentages are not equal to 100 because of missing data.

†Analyzed for 1156 patients (61%) with body mass index available.

Risk factors for frequent ED visits with acute asthma

Patients with more-severe asthma will require more-frequent ED visits compared with those with milder illness. The literature indicates that patients with severe or difficult-to-control asthma are at higher risk of future asthma exacerbations.²²⁻²⁴ Consistent with these findings, we further identified that frequent ED users are more likely to have several markers of severe asthma, such as previous hospital admissions and the current use of inhaled corticosteroids.

In addition, we were struck by the disproportionate health care related disparity for frequent ED visits for acute asthma. Consistent with the previous studies,^{5,7} we found that patients at highest risk of frequent ED visits were more likely to have public insurance or no insurance. The observed disparity suggests a persistent and uneven disease burden in these vulnerable populations. However, the causal role of insurance status to this disparity in health care utilization is unclear. Results of the previous studies indicate that differences in patients' health beliefs, less self-management education, and limited access to preventive care might lead to a heavier reliance on episodic symptom treatment in the ED.²⁵ On a related topic, and in agreement with our previous study,⁷ we found that having a primary care physician was not associated with a lower frequency of ED visits in either unadjusted or adjusted analyses. With the current attempt to shift care from the ED to primary care through the Affordable Care Act, it is important to avoid simplistic assumptions about the impact of assigning a primary care physician based on the frequency of ED visits made by this ED-based patient population. Given the observed substandard use of long-term control medications and suboptimal coordination with asthma specialists in the study population, our findings should encourage health care providers and policy makers to more critically examine how to optimize the impact of primary care assignment and actual primary care on uncontrolled asthma.

TABLE II. Acute asthma presentation and ED course according to frequency of asthma-related ED visits in the past 12 months

Variables	No ED visit (n = 1027 [54%])	1-2 ED visits (n = 538 [28%])	3-5 ED visits (n = 199 [11%])	≥6 ED visits (n = 126 [7%])	P value
ED presentations					
Duration of symptoms: ≤3 h before ED arrival (%)	9	9	13	13	.11
Vital signs, median (IQR)					
Initial respiratory rate (breaths/min)	20 (18-22)	20 (18-22)	20 (18-22)	20 (18-22)	.01
Initial oxygen saturation (%)	98 (96-99)	97 (95-99)	97 (96-99)	97 (95-99)	<.001
Initial PEF, L/min*	250 (175-305)	230 (160-300)	210 (150-300)	225 (170-300)	.21
Concomitant medical disorders (%)†	12	15	17	17	.09
ED treatment (%)					
Inhaled β-agonists	99	99	99	100	.58
Inhaled anticholinergics	69	74	76	71	.06
Systemic corticosteroids	75	84	82	78	<.001
Intravenous magnesium	6	11	14	20	<.001
Mechanical ventilation	1	2	1	4	.02
ED disposition (%)					
Sent home	87	75	76	75	<.001
Admission to observation unit	3	7	6	6	
Admission to hospital ward	7	14	15	15	
Admission to ICU	1	2	2	2	
Other (eg, left against medical advice)	1	2	2	2	
Discharge medications (%)‡					
Prescribed oral corticosteroids	72	78	74	80	.06
Prescribed inhaled corticosteroids	16	20	26	23	.005

ICU, intensive care unit; IQR, interquartile range; PEF, peak expiratory flow.

*Analyzed for 803 patients (42%) with initial PEF available.

†Defined by pneumonia, congestive heart failure, pneumothorax, arrhythmia, sinusitis, and otitis media.

‡Analyzed for patients sent home (n = 1544).

Potential limitations

Our study must be interpreted in the context of its study design. First, 5% of patients did not have data on prior ED visits, an exclusion that may have been a source of bias. However, the analytic cohort and patients with missing data were similar in demographic factors, asthma history, and current asthma medications. This similarity across groups argues against a significant bias. Second, this study relied on medical record review for data collection; therefore, error in data measurement is possible. For example, we might have missed ED visits for acute asthma in some patients who visited multiple EDs for their different asthma exacerbations. This would lead to underestimation of the number of frequent ED users. However, we used a previously applied standardized data collection system with uniform definitions and structured data forms.⁷ Furthermore, prior studies showed high agreement in rates of ED assessment and treatment for acute asthma between chart abstraction and direct observation, with kappa coefficients that ranged from 0.5 to 0.9.²⁶ Third, although only a small subset of these frequent ED users underwent allergy testing within the previous year, some of these patients might have been tested 2 or more years before the index ED visit. Fourth, this study examined only patients who presented with acute asthma, and visits to physician offices or other ambulatory care sites were not assessed. Nevertheless, our focus was on the characteristics and burden of frequent ED users. Our data are likely relevant to the millions of patients with asthma who visit EDs. Finally, our study population consisted mainly of urban teaching hospitals. Therefore, our inferences may not be generalizable to rural or more suburban (community) hospitals. However, urban areas have disproportionately high asthma morbidity; it is in precisely this population for which targeted preventive measures are most urgently needed.

TABLE III. Multinomial models of factors associated with frequency of asthma-related ED visits in past 12 months

Variables	1-2 (vs 0) ED visits		3-5 (vs 0) ED visits		≥6 (vs 0) ED visits	
	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value
Age						
18-29 y	1 (reference)		1 (reference)		1 (reference)	
30-39 y	0.89 (0.66-1.19)	.43	1.29 (0.82-2.03)	.27	1.35 (0.75-2.42)	.32
40-54 y	0.76 (0.57-1.00)	.050	1.39 (0.93-2.08)	.11	1.98 (1.19-3.28)*	.008*
Male sex						
	1.11 (0.86-1.42)	.43	1.59 (1.11-2.27)*	.01*	2.55 (1.65-3.96)*	<.001*
Race and/or ethnicity						
Non-Hispanic white	1 (reference)		1 (reference)		1 (reference)	
Non-Hispanic black	0.96 (0.70-1.32)	.80	1.42 (0.89-2.31)	.16	1.44 (0.79-2.65)	.24
Hispanic	0.96 (0.66-1.40)	.85	0.89 (0.49-1.62)	.71	1.16 (0.56-2.40)	.69
Other	1.13 (0.57-2.22)	.73	1.17 (0.37-3.66)	.79	0.51 (0.07-4.09)	.53
Having primary care physician						
	1.00 (0.76-1.33)	.98	1.11 (0.73-1.70)	.62	0.75 (0.46-1.20)	.23
Health insurance						
Private	1 (reference)		1 (reference)		1 (reference)	
Public	1.83 (1.38-2.34)*	<.001*	1.57 (1.05-2.35)*	.03*	2.02 (1.19-3.45)*	.01*
No insurance	1.85 (1.38-2.58)*	<.001*	1.33 (0.81-2.17)	.26	2.13 (1.16-3.92)*	.02*
Quartiles for median household income						
1 (lowest)	1.19 (0.83-1.70)	.36	1.38 (0.79-2.42)	.26	1.38 (0.69-2.75)	.37
2	0.72 (0.45-1.14)	.16	1.06 (0.54-2.08)	.87	0.69 (0.28-1.71)	.43
3	1.03 (0.65-1.62)	.91	0.91 (0.44-1.88)	.79	1.27 (0.55-2.94)	.58
4 (highest)	1 (reference)		1 (reference)		1 (reference)	
Ever admitted for asthma	2.77 (2.02-3.79)*	<.001*	2.64 (1.78-4.22)*	<.001*	3.99 (2.30-6.92)*	<.001*
Ever intubated for asthma	1.12 (0.75-1.67)	.59	0.99 (0.60-1.82)	.96	1.63 (0.93-2.85)	.09
Current use of inhaled corticosteroids	1.80 (1.39-2.32)*	<.001*	2.28 (1.59-3.26)*	<.001*	2.86 (1.84-4.45)*	<.001*

OR, Odds ratio.

*Statistically significant.

CONCLUSIONS

This large multicenter study of patients with asthma in 48 EDs demonstrated that approximately half of adults had at least 1 prior ED visit for acute asthma in the past year. Although this burden of frequent ED users was smaller than the previous multicenter data through the 1990s, the high percentage of frequent ED users continues to reflect the failure of current measures to manage these patients. Indeed, we found that only a small subset of these frequent users received outpatient management by asthma specialists and recommended long-term control treatment. These findings should encourage health care providers and policy makers to continue efforts to bridge the care gaps to further reduce asthma morbidity. The work is not yet done. Furthermore, we found that public insurance and no insurance status were significantly associated with a higher frequency of ED visits while having a primary care physician was not. The pathway through which these factors affect health care utilization is undoubtedly complex. For researchers, our observations should prompt further investigation of the special needs and health care barriers in this large patient population.

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FIGURE E1. Location of the 48 participating sites in the Multicenter Airway Research Collaboration³⁶ study.

TABLE E1. Site investigators at the 48 participating sites in the Multicenter Airway Research Collaborative36 study

Akron City Hospital	Kirk A. Stiffler, MD, MPH
Albert Einstein Medical Center	Stewart O. Sanford, MD
Allegheny General Hospital	Hannah Todorowski, BS
Baystate Medical Center	Howard A. Smithline, MD, MS
Ben Taub General Hospital	Michael G. Gonzalez, MD
Beth Israel Deaconess Medical Center	Nathan Shapiro, MD
Brigham and Women's Hospital	Daniel J. Pallin, MD, MPH
Brooklyn Hospital Center	Mark J. Leber, MD, MPH
Buffalo General Hospital	Jeanne M. Basior, MD
Carolinas Medical Center	D. Matthew Sullivan, MD
Christiana Hospital	John T. Powell, MD
Cooper Medical School of Rowan University	Brigitte M. Baumann, MD, MSCE
Detroit Receiving Hospital	Claire Pearson, MD, MPH
East Carolina University, Vidant Medical Center	John E. Gough, MD
Hartford Hospital	Michael J. Drescher, MD
Hennepin County Medical Center	Richard O. Gray, MD
Henry Ford Hospital	Richard M. Nowak, MD, MBA
John H. Stroger Jr Hospital of Cook County	Rashid F. Kysia, MD, MPH
Lincoln Medical And Mental Health Center	Muhammad Waseem, MD, MS
Long Island Jewish Medical Center	Robert A. Silverman, MD
Maricopa Medical Center	Frank LoVecchio, MD
Massachusetts General Hospital	Eva Tovar Hirashima, MD, MPH
Mercy Hospital of Philadelphia	Patrick Shen, MD
MetroHealth Medical Center	Rita K. Cydulka, MD, MS
Mount Sinai St Luke's and Mount Sinai Roosevelt Hospitals	Mark Clark, MD
New York Methodist Hospital	Theodore J. Gaeta, DO, MPH
New York Presbyterian Hospital/Weill Cornell Medical Center	Sunday Clark, ScD, MPH
Newark Beth Israel Medical Center	Eric J. Wasserman, MD
Oklahoma University Medical Center	Annette O. Arthur, PharmD
Oregon Health & Science University Hospital	Stephanie Nonas, MD
Palmetto Health Richland	Joseph S. Myslinski, MD
Sentara Norfolk General Hospital	Francis L. Counselman, MD
Shands Hospital at the University of Florida	J. Adrian Tyndall, MD, MPH
St Barnabas Hospital	Blanca Grand, DO
Stanford University Medical Center	Nancy E. Wang, MD
Temple University Hospital	Megan Healy, MD
Thomas Jefferson University Hospital	Bernard L. Lopez, MD, MS
Truman Medical Center Hospital	P. Charles Inboriboon, MD, MPH
University of Arkansas for Medical Sciences	Talmage M. Holmes, PhD, MPH
University of California Davis Medical Center	Suzanne S. Teuber, MD
University of California Irvine Medical Center	Mark I. Langdorf, MD, MHPE
University of California San Diego Medical Center	Brian Snyder, MD
University of California San Francisco Medical Center	Christopher Fee, MD
University of Maryland Medical Center	Rose M. Chasm, MD
University of New Mexico Health Sciences Center	Cameron Crandall, MD, PhD
University of Oklahoma School of Community Medicine @ Hillcrest Medical Center	Annette O. Arthur, PharmD
University of Texas Health Science Center at San Antonio	Dan Mosely, MD
University of Texas Southwestern Medical Center @ Parkland Memorial Hospital	Ava E. Pierce, MD
York Hospital	Ronald S. Benenson, MD

TABLE E2. Negative binomial regression model for factors associated with asthma-related ED visits in the past 12 months

Variables	Risk ratio (95% CI)	P value
Age		
18-29 y	1 [reference]	
30-39 y	1.05 (0.85-1.30)	.63
40-54 y	1.34 (1.06-1.70)*	.01*
Male sex	1.64 (1.30-2.06)*	<.001*
Race and/or ethnicity		
Non-Hispanic white	1 [reference]	
Non-Hispanic black	0.98 (0.72-1.32)	.89
Hispanic	0.96 (0.69-1.35)	.83
Other	0.96 (0.69-1.35)	.83
Having a primary care physician	0.98 (0.76-1.26)	.88
Health insurance		
Private	1 [reference]	
Public	1.38 (1.09-1.74)*	.007*
No insurance	1.39 (1.03-1.88)*	.03*
Quartiles for median household income		
1 (lowest)	0.78 (0.57-1.07)	.12
2	1.06 (0.75-1.49)	.74
3	1.15 (0.70-1.88)	.58
4 (highest)	1 [reference]	
Ever admitted for asthma	1.93 (1.53-2.45)*	<.001*
Ever intubated for asthma	1.44 (1.09-1.90)*	.009*
Current use of inhaled corticosteroids	1.65 (1.28-2.15)*	<.001*

*Results are statistically significant.