

A Prospective Multicenter Study of Patient Factors Associated With Hospital Admission From the Emergency Department Among Children With Acute Asthma

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Background: Recent studies show that objective measures such as peak flow rates are strongly associated with asthma admission among adults.

Objective: To identify factors associated with admission among children.

Methods: We performed a prospective cohort study as part of the Multicenter Airway Research Collaboration. Patients aged 2 to 17 years who presented to the emergency department (ED) with acute asthma underwent a structured interview in the ED and another by telephone 2 weeks later. The study was performed at 44 EDs in 18 US states and 4 Canadian provinces. The decision to admit was made at the discretion of the treating physician. Univariate analysis of risk factors for admission was followed by multivariate logistic regression.

Results: Of the 1178 eligible subjects, 275 (23%; 95% confidence interval, 21%-26%) were admitted or placed

into ED observation units. A multivariate model that included 12 characteristics measured at presentation and during the ED stay was associated with an area under the receiver operating characteristic curve of 0.91. Demographic factors were not independently associated with admission. Severity of symptoms (odds ratio, 1.3) and intensity of therapy both before and during ED visit correlated with the likelihood of admission. Previous admission for asthma ($P = .02$) and recent use of inhaled corticosteroids ($P = .04$) also were associated with admission. Peak flows were associated with admission but were infrequently (23% overall) measured.

Conclusion: Hospitalization for asthma exacerbation in children is primarily associated with clinical indicators in the ED and with historical factors such as previous asthma admission or intubation, recent use of corticosteroids, and comorbidity.

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IN THE UNITED STATES, approximately 5 million children are affected by asthma,¹ and almost 200 000 require hospital admission every year.^{2,3} Acute asthma is the most common medical emergency in children, and its incidence in the pediatric age range is thought to be increasing.³⁻⁵ The 10% of children with the most severe asthma account for three quarters of inpatient treatment days attributed to the disease.⁶ The final decision regarding whether children with asthma exacerbation can be adequately treated as outpatients or whether hospitalization is indicated is often made by emergency physicians. This decision is traditionally based on a broad constellation of factors; however, there is no consensus on which factors are important. For example, history and physical examination^{5,7-10}; response to therapy in terms of respiratory effort or comfort^{8,10-12} and more objective measures such as pulse oximetry^{9,12-14}

and spirometric^{9,10,14,15} measurements; quality and availability of outpatient care^{16,17}; extent of asthma understanding by the caretakers^{7,18,19}; ambient air quality and allergen load²⁰⁻²³; and general socioeconomic factors²⁴ have all been used by emergency department (ED) and primary care providers. Moreover, the relative contributions of each of these factors in decision making is unclear.

During the past decade, consensus panels such as the National Asthma Education and Prevention Program and the Global Initiative for Asthma have issued recommendations for the care of the asthmatic patient, both in the acute and chronic settings.²⁵⁻²⁷ These guidelines recommend making the admission decision for asthma on the basis of peak expiratory flow rate (PEFR) or other spirometric testing, coupled with historical, clinical, and social factors. Previous research indicates that physicians are only moder-

ately adherent to the recommendations made in these guidelines.²⁸⁻³³ For pediatric patients, who frequently are unable or unwilling to perform spirometric maneuvers, these guidelines may not be particularly useful in the admission decision.

The primary objective of this study was to determine the patient factors associated with hospital admission among children presenting to the ED with acute asthma.

PATIENTS AND METHODS

This study combines data from a prospective cohort study performed during October to December 1997 and April to June 1998, as part of the Multicenter Airway Research Collaboration.³⁴ Using a standardized protocol, investigators at 44 EDs in 18 US states and 4 Canadian provinces provided coverage for 24 hours per day for a median of 2 weeks and enrolled patients with acute asthma. All patients were treated at the discretion of the treating physician. Inclusion criteria were physician diagnosis of acute asthma, age 2 to 17 years, and informed consent of the parent or guardian. Twenty-five patients who were emancipated minors gave informed consent and were interviewed. Repeated visits by individual subjects (n=38) and patients who were discharged from the ED against medical advice (n=6) were excluded. The institutional review board at each of the 44 participating hospitals approved the study.

DATA COLLECTION

The ED interview assessed patients' demographic characteristics, asthma history, and details of their current asthma exacerbation. Data on ED management and disposition were obtained by chart review. All forms were reviewed by site investigators before submission to the Multicenter Airway Research Collaboration Coordinating Center in Boston, Mass, where they underwent further review by trained personnel and then double data entry.

DATA CONVENTIONS

Primary care provider status was assigned on the basis of the following question: "Do you have a primary care provider (such as a family doctor, pediatrician, or nurse practitioner)?" If yes, patients were asked to provide the name and address of their primary care provider. Median family income was estimated by means of patients' home ZIP codes.^{35,36} Patients aged 12 to 17 years (n=223) were asked directly about active (ie, never smoker, past smoker, or current smoker) and passive smoke exposure. Passive smoke exposure was determined by asking if anyone living with the patient or seeing the patient on a regular basis ever smoked while in the same room as the patient. The PEFR is expressed as a percentage of the patient's predicted value, based on age, sex, weight, and height.³⁷ Pulmonary index (PI) scores were calculated according to respiratory rate, accessory muscle use, wheezing, and inspiratory-expiratory ratio; based on a scale of 0 to 3 for each component of the PI, a total was calculated with a maximum PI of 12.³⁸ "Severe symptoms" during the preceding 24 hours was assigned to those reporting asthma symptoms "most of the time" or "severe" discomfort and distress due to their asthma.

STATISTICAL ANALYSIS

All analyses were performed with Stata 5.0 (Stata Corp, College Station, Tex). Data are presented as proportions (with 95% confidence intervals [CIs]), means (with SDs), or medians (with

interquartile ranges). Imputed values, calculated with the Stata impute command, were used to calculate the PI score when 1 of the elements was missing; patients missing more than 1 value were not assigned a PI score. The association between admission and other factors was examined with the χ^2 test, *t* test, and Wilcoxon rank sum test, as appropriate. Variables associated with admission at $P<.1$ were evaluated for inclusion in multivariate logistic regression models. Age and sex were included in the multivariate model because of their potential clinical significance. All *P* values are 2-sided, with $P<.05$ considered statistically significant.

RESULTS

DEMOGRAPHIC FACTORS

Of 1601 eligible pediatric patients presenting to the ED with acute asthma, 1184 (74%) were enrolled. Six patients who left against medical advice were excluded from analysis. Of 1178 analyzed patients, 275 (23%; 95% CI 21%-26%) were admitted; this includes 22 patients who were placed in an ED observation unit after the conclusion of ED treatment. (Excluding observation patients from the admitted cohort in the final regression models did not change the results.) The median admission rate by site was 20%, with an interquartile range of 11% to 31%; variability in the overall sample was accentuated by small numbers of patients at some sites. Age, sex, parental education level, household income, payer status, and affiliation with a primary care physician were similar among patients who were admitted and not admitted (**Table 1**). The possibility of a seasonal variation in admissions was examined by adjusting for period of enrollment, but this did not materially affect any of the results that follow (data not shown).

CHRONIC ASTHMA

Chronic asthma history and treatment of admitted patients differed in some respects from those of patients not admitted (**Table 2**). Admitted patients were more likely to have been previously hospitalized for asthma (ever and within 1 year), to have been previously intubated for asthma, and to have used inhaled corticosteroid (CS) agents during the preceding month (all $P<.05$). On the contrary, age at asthma diagnosis, history of ever having taken systemic CS therapy, tobacco exposure history, recent β -agonist use, number of unscheduled visits, and use of ED services did not differ significantly between the 2 groups.

ACUTE ASTHMA PRESENTATION

Patients' acute asthma presentation to the ED also differed in several important areas according to admission status (**Table 3**). Admitted patients presented most often with a duration of symptoms of less than a day, but more than 3 hours. They had used more β -agonists before ED evaluation. They were more likely to have severe symptoms with the index episode and several objective markers (respiratory rates, PI scores, and pulse oximetry measurements) of a more severe exacerbation. Among the 23% of children with PEFR measurements (n=276), those who were admitted had lower

Table 1. Demographic Characteristics of Patients With Acute Asthma, According to Admission Status*

Demographic Factor	Admitted (n = 275)	Not Admitted (n = 903)	Difference	95% CI
Age, mean, y	7.9	7.9	0.0	-4.1 to 4.1
Sex, % Female	40	41	-0.3	-6.9 to 6.3
Race, %				
White	18	18	-0.2	-5.3 to 5.0
Black	59	58	1.0	-5.6 to 7.7
Hispanic	19	23	-3.3	-8.7 to 2.1
Other	4	2	-2.5	-4.4 to -0.5
High school graduate, %	68	71	-2.7	-9.0 to 3.5
Estimated household income, mean, \$	30 862	30 167	696	505 to 886
Insurance status, %				
Private	41	38	3.6	-3.0 to 10.1
Medicaid	33	29	4.1	-2.1 to 10.3
Other public	15	18	-3.3	-8.0 to 1.6
None	11	15	-4.4	-8.8 to -0.1
Primary care provider status, %	92	91	1.8	-1.9 to 5.4

*CI indicates confidence interval.

Table 2. Chronic Asthma Characteristics of Patients With Acute Asthma, According to Admission Status*

	Admitted (n = 275)	Not Admitted (n = 903)	Difference	95% CI
Age at asthma diagnosis, %				
0-5 y	84	84	0.7	-4.2 to 5.6
6-11 y	14	13	0.3	-4.3 to 4.9
12-17 y	2	3	-1.3	-3.3 to 0.8
Ever taken systemic corticosteroid medicine for asthma, %	75	71	4.0	-2.0 to 9.9
Ever hospitalized for asthma, %	67	56	11.2	4.8 to 17.6
Ever intubated for asthma, %	8	4	3.7	0.4 to 7.1
Hay fever, %	46	43	3.3	-3.5 to 10.0
Current smoker, %†	8	13	-5.1	-8.9 to -1.3
Smoker exposure, %‡	38	39	-1.4	-7.9 to 5.2
Inhaled β -agonist during past 4 wk, %	73	74	-1.2	-7.2 to 4.7
Inhaled corticosteroid during past 4 wk, %	28	20	8.0	2.1 to 13.9
Other asthma medication during past 4 wk, %	21	17	3.7	-1.7 to 9.1
Most helpful asthma medication given by nebulizer, %	56	51	4.9	-1.8 to 11.6
No. of urgent clinic visits in past year, mean	2.9	2.7	0.2	-8.8 to 9.2
No. of ED visits in past year, mean	3.2	3.4	-0.3	-7.6 to 7.1
Admitted for asthma in past year, %	42	25	16.6	10.1 to 23.1
ED usual site for problem asthma care, %	60	64	-4.3	-10.9 to 2.3
ED usual source for asthma prescriptions, %	26	32	-6.0	-12.0 to 0.03

*CI indicates confidence interval; ED, emergency department.

†Restricted to patients aged 12 to 17 years (n = 223).

‡See "Patients and Methods" section for details.

PEFRs than those who were not admitted. Not surprisingly, younger patients were less likely to perform PEFR testing: among patients aged 2 to 5 years, only 6% were tested; aged 6 to 11 years, 44%; aged 12 to 13 years, 60%; and aged 14 to 17 years, 69%. Admitted children were also more likely to have a comorbid condition (eg, pneumonia, pneumothorax, bronchopulmonary dysplasia) complicating their asthma.

ED COURSE AND DISPOSITION

Characteristics of the patients' ED course are presented in **Table 4**. Every measured characteristic was significantly different between patients admitted and not admitted. In general, these data reflect more intensive

therapy during a longer period, with a lesser response among patients who were admitted after ED care.

ANALYSIS OF DATA ASSOCIATED WITH ADMISSION

Multivariate analysis of patient factors associated with hospital admission was performed (**Table 5**). The PEFR measurements were not included in the model because these values were recorded in a nonrepresentative minority of subjects (23%). The explanatory power of the final logistic regression model was assessed by developing a receiver operating characteristic curve to evaluate the degree to which the model captured factors that relate to a patient's risk of admission (Table 5). The area

Table 3. Characteristics of Index Asthma Exacerbation, According to Admission Status*

	Admitted (n = 275)	Not Admitted (n = 903)	Difference	95% CI
ED triage time, %				
Midnight to 7:59 AM	18	16	2.2	−2.9 to 7.4
8:00 AM to 3:59 PM	37	43	−5.3	−11.9 to 1.2
4:00 to 11:59 PM	44	41	3.1	−3.6 to 9.8
Duration of symptoms, %				
≤3 h	8	12	−4.3	−8.1 to −0.5
4–23 h	63	51	11.9	5.4 to 18.5
1–7 d	29	34	−5.3	−11.5 to 0.9
>7	0	3	−2.3	−3.6 to −1.0
No. of inhaled β-agonist puffs within 6 h of ED, median (interquartile range)†	6 (2 to 14)	3 (0 to 12)‡
Severe symptoms, %§	72	63	9.2	3.0 to 15.4
Initial respiratory rate, mean, breaths/min	38	30	7.9	2.8 to 13.0
Initial oxygen saturation, mean, %	93	96	−3.5	−4.6 to −2.4
Initial PEFR, mean, % predicted	36	50	−13.7	−13.8 to −13.6
Pulmonary index score, mean§	6	4	2.4	−0.4 to 5.3
Comorbid condition, %	7	4	3.4	0.1 to 6.8

*CI indicates confidence interval; ED, emergency department; ellipses, not applicable; and PEFR, peak expiratory flow rate.

†Each nebulizer treatment was counted as equivalent to 6 “puffs” from a metered-dose inhaler.

‡ $P < .001$.

§See “Patients and Methods” section for details.

||Available for 276 patients with initial peak flow value.

Table 4. Characteristics of ED Treatment and Course for Index Asthma Exacerbation, According to Admission Status*

	Admitted (n = 275)	Not Admitted (n = 903)	Difference	95% CI
No. of inhaled β-agonists in first hour, mean	2.4	1.5	0.9	−1.2 to 2.9
No. of inhaled β-agonists during ED stay, mean	5.4	2.4	3.0	−0.1 to 6.1
Given corticosteroid treatment, %	89	74	14.0	9.7 to 19.1
Received other asthma treatments in ED, %	62	34	27.6	21.0 to 34.1
ED length of stay, mean, min	232	153	79	62 to 97

*ED indicates emergency department; CI, confidence interval.

Table 5. Association of Patient Factors With Hospital Admission in Multivariate Logistic Regression*

	Odds Ratio	95% CI	P Value
Age (per increase of 5 y)	1.2	0.9–1.5	.30
Female	1.2	0.8–1.8	.41
Nonwhite	1.0	0.6–1.8	.99
Admitted for asthma during past year	1.7	1.1–2.8	.02
Not taking corticosteroids at time of ED arrival	0.3	0.2–0.6	.001
Duration of symptoms (per 12 h)	1.9	0.9–1.0	.16
No. of inhaled β-agonist puffs within 6 h of ED (per 10 puffs)	1.3	1.0–1.6	.04
Severity of asthma symptoms during past 24 h	1.3	1.0–1.8	.04
Oxygen saturation (per decrease of 5%)	2.2	1.6–3.0	<.001
Pulmonary index score	1.3	1.1–1.4	<.001
No comorbid condition	0.3	0.1–0.7	.007
No. of inhaled β-agonists during ED stay	2.1	1.8–2.4	<.001

*CI indicates confidence interval; ED, emergency department. The area under the curve for the model is 0.91.

under the receiver operating characteristic curve generated by the final model was 0.91, which suggests that the model captures a large proportion of factors that increase a patient's likelihood of admission. The estimates did not materially change when factors related to admission among adult patients (eg, having a high school education, estimated household income, insurance status, having a primary care provider, nebulizer as most help-

ful route for administering asthma medication, and asthma medications other than β-agonists and inhaled CSs)³⁹ were added to the final model (data not shown).

COMMENT

This prospective, multicenter study examined pediatric acute asthma presentations to North American EDs. This

is the largest study of its kind to evaluate admissions for acute asthma and factors associated with these admissions. Recent data from Multicenter Airway Research Collaboration studies in adult patients indicate that PEFR measurement is the single best predictive factor of admission for acute asthma exacerbation.³⁹ Many pediatric patients are unable or unwilling to perform PEFR testing; this measurement, therefore, is much less helpful in younger age groups. In the current study, only 23% of patients had PEFR measured, and the youngest patients were least well represented.

Where performed, however, PEFR was associated with the likelihood of admission (Table 3). Other factors clearly associated with admission that were identified in this analysis included severity of asthma symptoms at presentation, intensity of home and ED management (as measured by number of β -agonist treatments), the presence of a comorbid condition, and asthma history (previous admission or intubation and CS use). As would be expected, clinical indicators in the ED (pulse oximetry and PI score) were also associated with admission, but demographic factors such as sex and race, which have been predictive of admission among asthmatic adults,³⁹ were not significant in this analysis. Other investigators have sought to predict the likelihood of pediatric asthma admission from the ED. This work represents a body of literature separate and distinct from research on admission patterns in population-based cohorts of asthmatic children, and much of it was published 10 or more years ago.

In 1990, Kerem et al⁵ published their results of a prospective study of 200 children (aged 5.6 ± 3.1 years) who presented to the ED with acute asthma. On arrival and at disposition, a clinical score was assigned to each child on the basis of heart rate, respiratory rate, presence of pulsus paradoxus, severity of dyspnea, accessory muscle use, and degree of wheezing. The clinical score on disposition was the only factor predictive of admission. Among the components of the score, degree of dyspnea was the most reliable predictor. The authors concluded that the admission decision is based mainly on "careful clinical evaluation."⁵ This is consistent with our finding that the PI score—the components of which are respiratory rate, degree of wheezing, inspiratory-expiratory ratio, and use of accessory muscles³⁸—was strongly associated with admission.

Newcomb and Akhter¹⁵ reported in 1986 that "explicit, quantitative criteria for guiding [emergency room] disposition of asthma" were needed. Their protocol was based entirely on clinical and historical criteria, and indicated admission if the response to the first 2 nebulized β -agonist treatments was "poor." They conceded, however, the existence of a subset of "frequent visitors" (13% of their patients, who accounted for 66% of all relapses) for whom this approach might be too conservative.¹⁵ It should be noted that this study was published in 1986, before the proper role of CS therapy for pediatric asthma was well appreciated.

Skoner and colleagues⁸ in 1987 sought to develop a "pediatric predictive index" for asthma admission in 193 ED presentations among 156 children. The pediatric predictive index was calculated by means of inspira-

tory breath sounds, degree of wheezing, and respiratory rates. A score of zero correctly categorized 95% of admissions, but incorrectly categorized 34% of those who were discharged and did not relapse.⁸ These variables reflect clinical response to therapy and again are consistent with the PI score³⁷ used in the current study.

In 1984, Ownby et al¹⁰ studied 200 pediatric ED visits for asthma in patients cooperative with PEFR testing; using discriminant analysis, they selected the variables that best predicted disposition for the first 100 cases. These factors were initial PEFR, extent of treatment in the preceding 24 hours, age at onset of asthma, and number of previous admissions for asthma. The model was then tested on the next 100 visits. Although this combination correctly predicted disposition for 82% of the 200 cases, admission was not well predicted (6 of 18 correct in the first 100 cases and 0 of 15 in the confirmation cohort). The authors attributed the weakness of the model to the PEFR contribution and concluded that overall clinical status after treatment was the best predictor of admission.¹⁰ Meanwhile, Taylor¹⁴ found that the addition of PEFR data to a management guideline for pediatric asthma improved the accuracy of dispositions. Schuh et al⁹ in 1997 studied 120 asthmatic children aged 5 to 17 years who presented to the ED with forced expiratory volume in 1 second less than 50% of that predicted, and found that baseline characteristics were not predictive of the need for admission. By 2 hours after initiation of therapy, however, both predicted forced expiratory volume in 1 second less than 30% and total asthma score (composed of accessory muscle use, degree of wheezing, and degree of dyspnea) of 6 or greater were associated with the likelihood of admission.⁹

Twaddell and coworkers¹² in 1996 sought to determine whether a single assessment at the time of presentation could predict ultimate ED disposition. Children were assigned to 1 of 3 groups: those probably able to manage at home, those who may need admission, and those who clearly need admission. Of 53 children, 25 were assigned to the indeterminate group, clearly limiting the utility of this system. Eighteen of these patients were admitted.¹²

In 1994, Geelhoed et al¹³ evaluated 280 pediatric ED visits for acute asthma. They focused on the potential predictive ability of the presenting oxygen saturation for "poor outcomes" (admission, relapse, or need for intravenous aminophylline). Historical factors (age, age at onset of asthma, number of past admissions, duration of symptoms, and current and recent treatment) also were considered. Pulse oximetry was found to be a reliable and independent predictor of poor outcomes. Odds ratios for a poor outcome were 35 (95% CI, 11-150) for an arterial oxygen saturation of 91% or less compared with 96% or more, and 4.2 (95% CI, 2.2-8.8) for an arterial oxygen saturation of 92% to 95% compared with 96% or more.¹³ This finding is consistent with the current data, which indicate an odds ratio for admission of 2.2 (95% CI, 1.6-3.0) per 5% decrease in arterial oxygen saturation.

Taken together, along with the present data, it is apparent that spirometric data, when available, are valuable to emergency physicians making dispositions after

The Multicenter Airway Research Collaboration

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ED asthma care of children. In children for whom spirometry is not available or is unreliable, other objective measures such as pulse oximetry and asthma scoring systems are helpful. Historical factors such as pre-ED treat-

What This Study Adds

Recent studies show that objective measures such as peak flow rates are strongly associated with asthma admission among adults. Because determining peak flow is not always feasible in pediatric patients, we sought to identify factors associated with admission among children. Demographic factors were not independently associated with admission. Severity of symptoms (odds ratio, 1.3) and intensity of therapy both before and during ED visit correlated with the likelihood of admission. Previous admission for asthma ($P=.02$) and recent use of inhaled corticosteroids ($P=.04$) also were associated with admission. Peak flows were associated with admission but were infrequently (33% overall) measured.

In summary, hospitalization for asthma exacerbation in children is primarily associated with clinical indicators in the ED and with historical factors such as previous asthma admission or intubation, recent use of corticosteroids, and comorbidity. More attention to these variables may make disposition more predictable and consistent.

ment, history of previous endotracheal intubation for asthma, and previous admission are essential to elicit and record before making a disposition from the ED. Ultimately, however, perhaps the most reliable factor in this decision is the intensity of and response to bronchodilator therapy in the ED.

This study has some potential limitations. The EDs participating in the study typically were in academic medical centers, many of which support emergency medicine residency programs. Most site investigators had a research interest in asthma. Thus, these institutions may have been more likely than nonacademic centers to be familiar with consensus guidelines. In addition, academic EDs might have different practice and admission patterns than community hospitals.

Because we did not interview the physicians caring for these patients, we cannot state with certainty that the various factors found to be associated with admission actually played a role in the admission decision; the strongest associations, however, were for clinical indicators that clearly were apparent to the treating physician in real time. In addition, although we excluded 6 patients who signed out against medical advice from this analysis, we are aware that patient preferences and other subjective factors that may influence the decision to hospitalize a patient may not have been captured by our study design.

CONCLUSIONS

Hospitalization for asthma exacerbation in children is primarily associated with clinical indicators in the ED and with historical factors such as previous admission or intubation, use of CSs before the visit, and comorbidity. Although PEFR is predictive of admission when measured, it frequently cannot be, or is not, tested in the ED, even in academic EDs staffed by physicians with a research interest in asthma.

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