Medical and Social Determinants of Health Associated with Intensive Care Admission for Asthma in Children

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Abstract

Rationale: Risk factors for severe asthma exacerbations in children requiring admission to the intensive care unit (ICU) may occur in variety of medical, environmental, economic, and socioeconomic domains.

Objectives: We sought to characterize medical and sociodemographic risk factors among children who required admission to the intensive care unit for asthma.

Methods: Data were obtained from the Greater Cincinnati Asthma Risk Study, a population-based, prospective, observational cohort of children admitted for treatment of acute asthma or bronchodilator-responsive wheezing. Data collected on 774 children included race, socioeconomic status, allergen sensitization, environmental exposures, psychosocial strain, and financial hardship. Analyses compared children admitted to the ICU to those admitted to a medical inpatient unit.

Measurements and Main Results: One hundred sixty-one (20.9%) children required admission to intensive care. There was no difference in sex, race, insurance status, caregiver educational

level, income, financial strain, psychological distress, or marital status between the ICU and non-ICU cohorts. Risk for medication nonadherence assessed by parent report was not different between groups. Although previous hospital admission or emergency department visit history did not differ between the groups, prior ICU admission was more common among those admitted to the ICU at the index admission (27 vs. 16%, $P = 0.002$). Children requiring intensive care admission were more likely to be sensitized to multiple aeroallergens. Exposure to cigarette smoke (measured as salivary cotinine), although a risk factor for hospital admission, was negatively associated with risk of ICU admission.

Conclusions: Social and economic risk factors typically predictive of increased asthma morbidity, including exposure to tobacco smoke, were not associated with ICU admission among a population of children admitted to the hospital for treatment of acute asthma. Intrinsic disease factors, including allergic sensitization, may be more important predictors of ICU admission.

Keywords: asthma; intensive care unit; health disparities; asthma exacerbation; childhood asthma

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Respiratory conditions, including asthma, are the most common discharge diagnoses from pediatric hospitals in the United States (1, 2). Severe asthma exacerbations may

result in respiratory failure, pneumothorax, circulatory compromise, or death. Exacerbations requiring admission to the intensive care unit (ICU) have been

associated with increased risk of death from asthma even after the exacerbation has resolved (3, 4). Multiple studies have reported risk factors for ICU admission

for status asthmaticus with little consensus. Those risk factors include patient sex (5, 6), age (5–8), ethnicity (7, 9, 10), atopy (11), socioeconomic factors (7, 12), and exposures such as cigarette smoke (5, 13). Duration and severity of asthma, nonadherence to therapy, and previous asthma hospitalization have also been characterized as risk factors for severe asthma exacerbation (6, 12, 14–17). Furthermore, psychosocial factors such as depression and stress have also been linked to exacerbation risk (18, 19). Importantly, children who are members of minority groups and live in disadvantaged, urban environments have significantly more asthma morbidity, higher healthcare use, and greater risk of dying from asthma (1, 2, 20–25).

We have previously shown in a prospective cohort of children admitted to the hospital for treatment of acute asthma or bronchodilator-responsive wheezing that those who are black and live with financial and social hardship have greater risk of hospital readmission within 12 months (26). Similar demographic, financial, or psychosocial factors may also be associated with severe asthma exacerbation necessitating ICU admission. Most previously published investigations regarding ICU admission for asthma are retrospective chart reviews or case-control studies and have been limited by small numbers of patients and/or lack of a diverse patient population. We sought to determine medical and sociodemographic factors associated with admission to the ICU among a population-based, prospective cohort of children hospitalized for asthma exacerbation.

Methods

Data were obtained from the Greater Cincinnati Asthma Risk Study (GCARS), a prospective, observational cohort at Cincinnati Children's Hospital Medical Center (CCHMC). Given data from the Ohio Hospital Association indicating that nearly 85% of asthma admissions for children aged 1 to 16 years within our eight-county primary service area occur at CCHMC, our accrued admission sample was considered to be population based (27, 28). The study design and population have previously been described (26). Children, aged 1 to 16 years, were eligible for study

enrollment if the admitting physician used our institution's evidence-based clinical pathway for acute asthma or bronchodilator-responsive wheezing. Children who were removed from the pathway before discharge, had significant respiratory or cardiovascular comorbidities (e.g., cystic fibrosis, congenital heart disease), resided outside of the eight-county primary service area, or whose primary caregiver did not understand written or spoken English (~2% of those otherwise eligible) were excluded. Previous admission to the hospital was not an exclusion criterion. Seven hundred seventy-four children (59% of those eligible) were enrolled during the 14-month enrollment period between August 2010 and October 2011.

Demographic data including age, race, household income, parental education, indoor environmental exposures, measures of psychosocial strain, and financial hardship were collected from the primary caregiver at the time of admission. Asthma severity was determined based on responses to a questionnaire containing NHLBI guideline-based (29) questions administered on admission to the hospital. Sensitization to common inhalant allergens was determined by measurement of serum allergen-specific IgE (ImmunoCAP; Quest Diagnostics, Madison, NJ). Allergens assayed were cat dander, dog dander, German cockroach, American cockroach, dust mite (both *Dermatophagoides pteronyssinus* and *Dermatophagoides farinae*), ragweed, white oak, *Alternaria*, *Aspergillus*, and mouse. Exposure to sources of indoor allergens (mold, pests, furry pets, carpeting) was determined by self-report. Tobacco smoke exposure was determined by salivary cotinine concentration and questionnaire ("Does anyone smoke inside your home [e.g., you, relatives, friends]?"). Methodology for collecting and processing salivary cotinine specimens has previously been described (13). Exposure to outdoor air pollutants was measured as elemental carbon attributed to traffic and estimated by applying a validated land use regression model (30, 31) to the reported primary residence of the enrollee. The address was geocoded using ArcGIS version 9.3 (ESRI, Redlands, CA).

Financial or social hardship was assessed by asking if parents were unable to find work or borrow money from a friend or relative in time of need and whether they

owned a car or their home. An affirmative answer to the first two questions or negative answers to ownership questions were considered indicators of hardship. Parent psychological stress was evaluated using the Kessler 6 (K6) Psychological Distress Scale (32), a validated questionnaire consisting of six questions about emotional states, each with five response levels; composite score ranges from 0 to 24. The K6 items measure nervousness, hopelessness, irritability, negative affect, fatigue, and worthlessness experienced over the past 30 days. Risk for nonadherence to therapies was assessed using questions from a subscale of Baumann's nonadherence measure, a tool that has been associated with increased morbidity, including increased healthcare use (33).

Criteria for admission to the ICU were met when a child demonstrated inadequate response to an emergency department (ED) protocol for asthma exacerbation or had respiratory deterioration after admission to the medical floor. The ED asthma protocol included frequent nebulized albuterol plus ipratropium, intravenous magnesium, and 1 hour of continuously nebulized albuterol. Children with minimal or transient response to the protocol were admitted. Children were not admitted to the ICU unless they continued to have respiratory distress or wheezing requiring bronchodilators more often than every 60 minutes after the above protocol. A respiratory distress score (CCHMC evidence-based guideline) was used to guide decision making regarding hospital admission. The study was approved by the Institutional Review Board of CCHMC. Informed consent was obtained from the patient's parent or guardian; assent was obtained from children aged 10 years and older.

Statistical Analyses

Cross-sectional analyses were performed comparing children who were admitted to the ICU during the index admission to those who did not require ICU admission. Children were included in the ICU group regardless of whether they were admitted to the ICU from the ED or from the medical ward after worsening respiratory status. Bivariate associations compared ICU and non-ICU children with respect to demographics, socioeconomic indicators, hardship, allergen sensitization, and environmental exposures using chi-square

statistics or Fisher exact test, as appropriate. A secondary outcome measure was readmission to the hospital within 12 months of the index admission. Analyses comparing readmission for children with ICU versus non-ICU at index admission were performed using chi-square or Fisher exact test. Multivariate analysis was

performed using logistic regression to exclude potential confounding factors. A stepwise selection procedure was used to identify final logistic variables. The initial model included demographic variables age, sex, race, insurance status, caregiver education, and variables regarding sensitization and exposure that were

significant in initial comparisons between the ICU and non-ICU cohorts. Further analysis was performed to identify potential interactions between home environmental exposure and allergen sensitization. The final model included only those variables that remained significant at the 0.05 level. All analyses used SAS statistical software (version 9.3; Cary, NC).

Table 1. Demographic, socioeconomic, and hardship information for intensive care unit versus non-intensive care unit patients

Characteristic	ICU	Non-ICU
No. of patients	161	610
Age, yr*		
<4	44 (27)	251 (41)
4–11	97 (60)	298 (49)
≥12	20 (12)	61 (10)
Sex		
Male	106 (66)	394 (65)
Race		
White	49 (30)	204 (33)
Black/African American	91 (57)	348 (57)
Multiracial	17 (11)	51 (8)
Other	2 (2)	6 (1)
Insurance		
Private	38 (22)	133 (22)
Public	112 (71)	447 (73)
Self-pay	7 (4)	20 (3)
Other	2 (1)	8 (1)
Missing	2 (1)	2 (1)
Annual Income, \$		
<15,000	54 (34)	206 (34)
15,000–29,999	34 (21)	176 (29)
30,000–44,999	23 (14)	85 (14)
45,000–89,999	32 (20)	92 (15)
≥90,000	15 (9)	40 (7)
Missing	3 (2)	11 (2)
Caregiver education		
High school graduate or less	72 (45)	267 (44)
Some college or 2-yr college/technical school graduate	61 (38)	254 (42)
College graduate or more	26 (16)	85 (14)
Unknown/missing	2 (1)	4 (1)
Marital status		
Single	94 (59)	388 (64)
Married	45 (28)	163 (27)
Divorced/widowed/separated	20 (12)	57 (9)
Missing	2 (1)	2 (<1)
Financial and social hardship		
Unable to find work	63 (40)	278 (46)
Unable to borrow money	59 (38)	263 (43)
Does not own home	118 (74)	478 (79)
Does not own car	40 (5)	174 (29)
Patients receiving controller medications†	79 (49)	238 (39)
Asthma severity		
Intermittent	106 (66)	441 (72)
Mild persistent	26 (16)	85 (14)
Moderate persistent	15 (9)	54 (9)
Severe persistent	11 (7)	27 (4)
Missing	3 (2)	3 (1)

Definition of abbreviation: ICU = intensive care unit.

Data presented as n (%) unless otherwise noted.

* $P < 0.001$.

† $P < 0.01$.

Results

Complete demographic data were available for 771 of the 774 children enrolled in the study. Fifty-seven percent were black, one-third had an annual income less than \$15,000, and 70% were Medicaid insured. One hundred sixty-one children (20.9%) required admission to the ICU. Ninety-one percent of these patients were admitted to the ICU directly from the ED. The remaining 9% were admitted to the pediatric ward but transferred to the ICU for worsening respiratory status.

There were no differences in sex, race, insurance status, annual income, educational level of caregiver, or marital status between the ICU and non-ICU cohorts. The groups also did not differ in site of usual asthma care (primary care, ED, or specialist [data not shown]). However, there were differences in age distribution between the groups, with a higher proportion of older patients (age > 4 yr) in the ICU group ($P < 0.001$, Table 1). Significantly more children admitted to the ICU were receiving controller medications (inhaled corticosteroids [ICS], leukotriene receptor antagonist, or ICS and long-acting β -agonist) (Table 1). There was no difference between the ICU and non-ICU groups on any measure of risk for nonadherence (see Table E2 in the online supplement). There were no demographic or medical differences between children admitted to the ICU from the ED and those transferred into the ICU for clinical worsening after admission (data not shown).

Financial and Social Hardship

Approximately 40% of parents of ICU patients and 46% of parents of non-ICU patients were unable to find work despite seeking employment; a similar percentage (38% ICU, 43% non-ICU) reported that they had no resource for borrowing money in time of need (Table 1). Few families

Table 2. Environmental exposures and atopic markers

	ICU	Non-ICU	P Value
Exposure			
Salivary cotinine $\geq$ LOD	104 (64.6)	465 (76.2)	<0.01
Salivary cotinine $<$ LOD	42 (26.1)	94 (15.4)	
Missing	15 (9.3)	51 (8.4)	
Salivary cotinine, mean (SD), pg/mL	412 (794)	767 (1,734)	0.01
Smoker in the home, yes	34 (21.1)	144 (23.6)	0.54
Ecat $\geq$ median	81 (50.3)	297 (48.7)	0.67
Ecat $<$ median	76 (47.2)	301 (49.3)	
Missing	4 (2.5)	12 (2)	
Atopic markers			
Allergen sensitization*			
Cat dander	77 (48)	203 (33)	<0.001
Dog dander	90 (56)	259 (42)	<0.01
German cockroach	11 (7)	50 (8)	0.74
American cockroach	32 (20)	104 (17)	0.44
Dpter	72 (45)	207 (34)	<0.01
Dfari	73 (45)	218 (36)	<0.05
Ragweed	45 (28)	169 (28)	0.84
White oak	52 (32)	178 (29)	0.58
<i>Alternaria</i>	75 (47)	213 (35)	<0.01
<i>Aspergillus</i>	69 (43)	199 (33)	<0.05
Mouse	29 (18)	63 (10)	<0.01
Season			<0.05
Spring	28 (17)	148 (24)	
Summer	24 (15)	77 (13)	
Fall	77 (48)	309 (51)	
Winter	32 (20)	76 (13)	
No. of positive sIgE tests			<0.05
0	30 (19)	153 (25)	
1–2	16 (10)	87 (14)	
≥ 3	99 (62)	300 (49)	
Missing	16 (9)	70 (12)	

Definition of abbreviations: Dfari = *Dermatophagoides farinae*; Dpter = *Dermatophagoides pteronyssinus*; Ecat = emissions attributable to carbon; ICU = intensive care unit; LOD = limit of detection; sIgE = specific immunoglobulin.

Data presented as n (%) unless otherwise noted.

*sIgE to allergen is positive at >0.35 kU/L.

owned a home (26% ICU, 21% non-ICU), but most owned a car (75% ICU, 71% non-ICU). None of these differences were statistically significant (Table 1). Likewise, there were no differences in degree of psychological distress as measured by total score or any individual category of the K6 between families of ICU patients and those admitted to the medical service (non-ICU, 5.15 ± 4.48 ; ICU, 5.16 ± 4.89 ; Figure E1).

Healthcare Use

The ICU and non-ICU groups had similar need for urgent visits for respiratory symptoms within the week before admission. There was no difference between groups in history of ED visit or admission to a general pediatric service for wheezing within 12 months before the index admission (Table 3). Significantly

more ICU patients reported prior admission to the ICU (ICU, 27%; non-ICU, 16%; $P = 0.002$; Table 3). To evaluate the possibility that history of ICU stay subjectively influenced the decision to admit to the ICU for the study index admission, we examined the episode acuity score (CCHMC evidence-based guideline) of ICU participants who did and did not have a history of previous ICU admission. There was no difference in mean score between those with and without prior ICU admission (3.92 ± 2.32 and 4.03 ± 2.04 , respectively; maximum score, 8).

There was no difference between the ICU and non-ICU cohorts in the proportion of children who required ED visit or hospitalization over the ensuing 12 months (46.6 vs. 42.3%, respectively; $P = 0.33$). However, significantly more

patients in the ICU during the index admission required ICU care on subsequent admissions compared with those in the non-ICU group (11.2 vs. 4.9%, respectively; $P = 0.003$).

Atopy and Exposures

Complete data on allergen exposure and sensitization were available for 670 patients. Children admitted to the ICU were more likely to be sensitized to multiple allergens, largely indoor allergens, such as cat, dog, and dust mite (cat: ICU, 48%; non-ICU, 33%; $P < 0.001$; dog: ICU, 56%; non-ICU, 42%; $P < 0.01$; *Dermatophagoides pteronyssinus*: ICU, 45%; non-ICU, 34%; $P < 0.01$; *Dermatophagoides farinae*: ICU, 45%; non-ICU, 36%; $P < 0.05$; Table 2). Sensitization to cockroach did not differ between the two groups (German cockroach: ICU, 7%; non-ICU, 8%; $P = 0.74$; American cockroach: ICU, 20%; non-ICU, 17%; $P = 0.14$; Table 2), but mouse sensitization was more prevalent in the ICU group (18 vs. 10%; $P < 0.01$). Further analysis revealed that children sensitized to a higher number of allergens were at increased odds of ICU admission than those with no or few sensitizations. When adjusted for age and sex, children who were sensitized to cat or dog dander had significantly higher odds for admission to the ICU (odds ratio [OR], 1.85; 95% CI, 1.24–2.75; and OR, 1.71; 95% CI, 1.14–2.55, respectively). Although there was a significant association between report of current exposure in the home to furry pets and sensitization to dog and cat, and to carpet in the home and sensitization to *Alternaria*, there was no association with increased odds of ICU admission.

Exposure to tobacco smoke was determined by questionnaire and salivary cotinine level. Although fewer than 25% of the caregivers reported a smoker in the home, salivary cotinine levels were detectable in 65% of the ICU cohort and 76% of the non-ICU group ($P < 0.01$, Table 2). Moreover, a significantly higher proportion of ICU patients had cotinine below limit of detection compared with those in the non-ICU group. In addition, the mean salivary cotinine level was lower among the ICU cohort than those admitted to the medical unit (ICU, 412.3 pg/mL; non-ICU, 767.2 pg/mL; $P = 0.01$; Table 2). Multivariate logistic regression analyses

Table 3. Healthcare use in 12 months before index admission

	ICU	Non-ICU	P Value
ED visit in prior 12 mo			
0	74 (46)	291 (48)	0.12
1	39 (24)	96 (16)	
≥2	46 (29)	219 (36)	
Missing data	2 (1)	4 (<1)	
Admission in prior 12 mo			
0	106 (66)	440 (72)	0.39
1	34 (21)	99 (16)	
≥2	19 (12)	66 (11)	
Missing data	2 (1)	5 (1)	
Previous ICU ever			
Yes	43 (27)	99 (16)	0.002
No	115 (71)	506 (83)	
Missing data	3 (2)	5 (1)	

Definition of abbreviations: ED = emergency department; ICU = intensive care unit.
Data presented as n (%).

revealed that after adjusting for age, sex, season, and number of positive specific IgE measures, the cotinine association with decreased odds for ICU admission remained significant (OR, 0.73, $P = 0.02$; Table 4), as did the association of multiple allergic sensitization and odds of ICU admission. There was no difference in traffic-related air pollutant exposure elemental carbon attributed to traffic between groups (Table 2).

The seasonal distribution of admissions was different between the ICU and non-ICU groups (Table 2). Although the greatest number of admissions for both groups was in the fall, a slightly higher proportion of the ICU admissions occurred during the winter.

Analyses by Age Group

Because age distribution was significantly different between the ICU and non-ICU groups, and the pathophysiology of wheezing may be different for older and younger children, further analyses were performed separately for children younger

than 4 years and those 4 years and older. The age groups differed mainly on prior healthcare use. Younger children admitted to the ICU had significantly more ED visits in the previous year than those in the non-ICU group ($P = 0.002$), whereas older children in the ICU cohort had more previous hospitalizations both on a general inpatient unit ($P = 0.02$) and in the ICU ($P = 0.003$, Table E1). There were no differences between ICU and non-ICU groups in any sociodemographic variables regardless of age group. However, parents of younger children in the non-ICU group reported more difficulty borrowing money than those in the ICU group (data not shown).

Discussion

Multiple studies, including GCARS, have described increased risk of asthma morbidity related to race and sociodemographic disparities (20–26, 34, 35). Multivariate analysis of the entire

GCARS study cohort revealed that 36% of the observed racial differences in hospital readmission were explained by financial and social hardship, and socioeconomic status (SES) and hardship together accounted for almost half of the disparity (26). Although we expected to find even greater disparities in the subgroup of patients who required admission to the ICU, there was no difference between the ICU and non-ICU groups in sociodemographic characteristics. When race, psychological stress, and social or economic hardship were examined at index admission, there was no difference between the ICU and non-ICU cohorts. Therefore, race, SES, and hardship all contributed to risk for overall readmission for asthma, but they did not serve as predictors for initial severe asthma exacerbation. Other studies also have failed to find race as a risk factor for admission to the ICU (34–38).

Although we did not measure adherence directly, we did not demonstrate any difference between groups in risk for nonadherence on the basis of answers to a validated tool that has been used in a similar population (33). This was an unexpected finding, because nonadherence to medications has been reported as common in difficult asthma (39–41) and associated with poor clinical outcomes, including admission to the ICU (9, 42, 43). A recent metaanalysis of studies examining the association between medication adherence and severe asthma exacerbations concluded that adherence to medications was associated with fewer severe exacerbations (41).

We also predicted that patients requiring ICU admission would have more readmissions and/or healthcare use for asthma over the ensuing 12 months. Yet, the overall readmission (ED, hospital, or ICU) proportion was the same for ICU patients and non-ICU patients. Still, a significantly higher proportion of patients hospitalized in the ICU during the index admission required another admission to the ICU over the next 12 months than the non-ICU group. This is consistent with our finding that patients in the ICU at index admission were more likely to report a prior ICU admission. Yet the comparability of the index acuity scores between enrollees

Table 4. Multivariate analysis of environmental exposures and risk of intensive care unit admission

Exposure	β	SE	Wald Chi-Square	P Value
Sensitized*	0.3788	0.1673	5.1242	0.02
Salivary cotinine	−0.00031	0.000141	4.9912	0.03

Variables included in the initial model were age, sex, season, and number of positive specific immunoglobulin. The final model shown above includes only those variables that remained significant.

*Sensitized to three or more allergens.

with and without prior ICU admission argues against subjective bias in the decision to admit children with previous ICU history. Our data corroborate those of previous studies that reported children who require ICU admission for asthma are at increased risk for subsequent ICU admission (5, 14, 15, 36, 44). Our ICU readmission percentage of 11% is commensurate with ICU readmission data reported by Carroll and colleagues (44) (11%) and Sheikh and colleagues (45) (10%), although other authors have reported higher readmission percentages (17–24%) (42, 46, 47).

Although a variety of risk factors for severe asthma exacerbation previously have been reported, including secondhand tobacco smoke (SHS) exposure, adolescent age, overweight, family history, sensitization to fungal antigens, and respiratory infection, the most commonly reported association is between ICU admission and atopy (6, 11, 12, 15, 37, 48, 49). Allergically sensitized patients in our study, specifically those with sensitization to indoor allergens, were more likely to be admitted to the ICU. Sensitization to dog and cat significantly increased the odds of ICU admission independent of reported exposure to furry pets. These findings are similar to those of van den Bosch and colleagues, who found that allergic sensitization and allergen exposure in the home were significant risk factors for ICU admission (11). The increased degree of sensitization to indoor allergens in ICU patients may also help explain the observation of a disproportionate number of ICU admissions compared with general ward admissions for asthma during the winter months, when exposure to indoor allergens is increased. Increased likelihood of respiratory viral infection could also contribute to the higher percent of ICU admissions for asthma exacerbation during winter months. Patients with asthma who are sensitized to environmental allergens have an impaired immune response, which may predispose to exacerbations induced by viruses (50, 51). Interaction between atopy and viruses has been shown to increase not only the number of viral illnesses but also the likelihood of admission for asthma exacerbation for atopic children (52, 53).

One unexpected finding is that tobacco smoke exposure, measured by salivary cotinine, was more prevalent in patients admitted to the pediatric unit than in those admitted to the ICU. A previous report on the association of reported and measured tobacco smoke exposure demonstrated that detectable cotinine was present in almost 80% of the overall GCARS population and was associated with increased risk of readmission within 12 months (13). A recent retrospective study that combined data from two children's hospitals examined the relationship of history of SHS exposure and asthma exacerbation severity among hospitalized children (54). No cotinine measures were obtained. Reported exposure to SHS was not associated with risk of ICU admission in bivariate analysis, and there was only a trend toward increased risk of ICU admission with linear regression controlling for age, race/ethnicity, sex, insurance status, oxygen supplementation, ICS use, and concurrent respiratory infection (OR, 1.5; 95% CI, 1.0–2.1). Our results show both lower mean cotinine level in the ICU group and a negative relationship with detectable cotinine levels and ICU admission. A possible explanation for our finding is that parents of children admitted to the ICU were aware of the severity of their child's disease and were then less likely to smoke or to avoid smoking near their children. Although previous reports have suggested good correlation with report of smoke exposure and cotinine measures, our data suggest that for studies of acute asthma and exposure risks, use of a biomarker like cotinine may provide more reliable results than a questionnaire.

Our study is one of the largest prospectively enrolled cohorts assembled to identify medical, environmental, and sociodemographic factors related to health disparities in hospitalized children with asthma. The sociodemographic information was further strengthened by the measures of financial hardship and psychological stress. There are, however, several limitations to the study. We did not obtain nasal samples to identify the role of respiratory viruses in severity of asthma exacerbations and ICU admission in our population. Furthermore, home allergen exposure was obtained by parent self-report rather than by direct measurement.

The combination of sensitization and exposure to offending allergens has been shown to contribute to asthma exacerbations (52–56), and measurement of allergen in the home would have provided a more reliable indication of exposure than parent report. Third, we did not evaluate appropriateness of medical treatment or directly assess adherence in our study and so were unable to exclude noncompliance to prescribed therapy or undertreatment as factors in severe asthma exacerbation. Yet, we identified no difference in risk for nonadherence between the groups. Last, ICU admission may also reflect refractoriness to treatment with short-acting β -agonists and glucocorticoid as a result of altered pharmacokinetics, but we did not collect data to assess this.

In conclusion, health disparities and psychosocial factors previously shown to be associated with asthma morbidity and hospitalization were not present in greater degree for patients requiring admission to the ICU. The lack of significant differences between the ICU and non-ICU cohorts in race, SES, risk for nonadherence, and markers of financial, social, and psychological strain supports underlying biologic mechanisms and environmental exposures rather than contextual factors predisposing to severe asthma exacerbations. Our findings suggest that children older than age 4 years hospitalized for treatment of severe asthma exacerbations that require ICU treatment are likely to have multiple allergen sensitization and are at risk of future ICU admissions. Interventions could target allergy testing for children who require ICU admission and subsequent aggressive asthma and allergy treatment for those with significant (three or more) sensitizations. Environmental interventions aimed at reduction of allergen exposure may also be helpful. Further investigation could focus on how allergen sensitization and exposure profiles of children who require hospital admission for severe asthma exacerbations might be incorporated into clinical and environmental interventions aimed at reducing both morbidity and disparities. ■

Author disclosures are available with the text of this article at www.atsjournals.org.

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