
High asthma prevalence and increased morbidity among rural children in a Medicaid cohort

Robert S. Valet, MD*†; Tebeb Gebretsadik, MPH‡; Kecia N. Carroll, MD, MPH§; Pingsheng Wu, PhD*†‡; William D. Dupont, PhD‡; Edward F. Mitchel, MS||; and Tina V. Hartert, MD, MPH*†

Background: Urban children represent a group at high risk for asthma development and adverse asthma outcomes. Although rural children also encounter sociodemographic disparities that might be expected to worsen asthma, asthma in the rural United States is poorly studied.

Objectives: To determine rural-urban differences in childhood asthma diagnosis and morbidity.

Methods: We studied a statewide population of 117,080 children continuously enrolled in Tennessee Medicaid from birth through the sixth year of life, using linked Tennessee Medicaid, vital records, and pharmacy claims databases to determine asthma diagnosis and residence.

Results: The cohort was 45% urban, 23% suburban, and 33% rural. Compared with urban children, rural children were more likely to be white, have a history of bronchiolitis, and have mothers who smoked. Eleven percent of urban, 12% of suburban, and 13% of rural children met study criteria for asthma diagnosis (adjusted odds ratio for rural children, 1.16; 95% confidence interval, 1.09–1.24; adjusted odds ratio for suburban children, 1.22; 95% confidence interval, 1.14–1.30; with urban as the referent; $P < .001$). Rural children had greater use of outpatient asthma care, whereas urban children had greater use of inhaled corticosteroids. Compared with urban children, rural children had fewer asthma emergency department visits but were hospitalized for asthma at similar rates and had similar use of asthma rescue medications.

Conclusion: In this pediatric Medicaid population, rural children had increased asthma prevalence and similar asthma morbidity compared with urban children but differences in patterns of asthma care and resource use, suggesting that optimal interventions for asthma may differ in rural compared with urban populations.

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INTRODUCTION

Urban children, particularly those who are members of disadvantaged minority groups, are well understood to represent a group with high asthma prevalence and increased asthma morbidity.^{1–3} In contrast, little information about the burden of asthma among rural children is available, even though 21% of the US population lives in rural areas,⁴ and residents of the rural United States encounter many of the same socioeconomic disparities seen in inner-city urban populations that might be expected to worsen asthma outcomes.^{5,6} Compared with the nonrural US population, residents of the rural United States have lower median family income, lower educational attainment, a higher rate of uninsurance, greater reliance on government insurance programs when insured, and a lower

supply of physicians, particularly subspecialists, per capita.^{5,6}

Asthma prevalence and morbidity are directly proportional to poverty independent of race,^{7–11} and, indeed, in Tennessee, both poverty and yearly hospitalization rates for asthma are increased in rural counties compared with urban and suburban counties.⁴ A rural, poor, heavily African American cohort of children in Arkansas was found to have a high asthma prevalence (28%), among whom 79% had persistent asthma symptoms.¹² A comparison of rural and urban schoolchildren in Arkansas revealed similar asthma prevalence by residence but increased prevalence of symptoms of uncontrolled asthma among the rural children.¹³ An analysis of hospital discharge information from Mississippi found an increased rate of emergency department (ED) care and hospitalization for asthma among residents of the rural Mississippi Delta compared with metropolitan Jackson, and this difference persisted after controlling for covariates.¹⁴

However, there are few additional published studies comparing health outcomes for asthma in rural vs urban US populations, even though residents of the rural United States represent a disadvantaged, medically underserved population^{5,6} that might be expected to have differences in asthma outcomes and health care use. We hypothesized that rural children represent a group with significant asthma prevalence and morbidity and different patterns of health care resource use based on available services. To address this question,

Affiliations: * Division of Allergy, Pulmonary, and Critical Care Medicine, Department of Medicine, † Institute of Medicine and Public Health, and ‡ Departments of Biostatistics, § Pediatrics, and || Preventative Medicine, Vanderbilt University School of Medicine, Nashville, Tennessee.

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we studied 117,080 children born between 1995 and 2000 who were enrolled continuously in Tennessee Medicaid (TennCare) until the age of 5½ years to determine the prevalence of asthma in rural vs urban children in this cohort; furthermore, among those children with asthma, we identified differences in outpatient care use and adverse asthma outcome measures.

METHODS

This is a population-based birth cohort study of 117,080 children born in Tennessee between 1995 and 2000 continuously enrolled in TennCare until the age of 5½ years, with no more than 60 days of nonenrollment between the ages of 3½ and 5½ years. This cohort represented approximately 25% of all live births in Tennessee during the study period.¹⁵

Linked TennCare database, pharmacy, and vital records files were used to obtain data on maternal and child demographics, atopic disease diagnosis, and medication use. Using the child's county of residence and the current Office of Management and Budget classification of counties,¹⁶ children were classified as urban (residing in a central county within 1 of Tennessee's 4 standard metropolitan statistical areas [SMSAs]), suburban (residing in a noncentral county within an SMSA), or rural (residing in a county outside an SMSA).

For mothers of children in the cohort who were also enrolled in TennCare, maternal asthma was determined using an algorithm that incorporates capture of the *International Classification of Diseases, Ninth Revision (ICD-9)* diagnosis code 493 for hospital care and outpatient visits, as well as asthma medication use, as has been previously described.¹⁷

For children in the study, the prevalence of asthma was determined from the ages of 4 to 5½ years. An 18-month window was chosen to capture at least 1 well visit for minimally symptomatic children presenting once a year for routine preventive care to their physician. Asthma diagnosis was defined using a validated algorithm¹⁸ that required an *ICD-9* diagnosis code of 493 in any field for outpatient, ED, or inpatient care or use of 1 or more asthma-specific anti-inflammatory medications. This algorithm has been shown to be 90% sensitive and 95% specific for identifying asthma compared with a "gold" standard of known physician diagnosis.¹⁸ Allergic rhinitis was defined by the presence of 1 or more *ICD-9* diagnoses and atopic dermatitis by the presence of 2 or more *ICD-9* diagnoses from the age of 3½ to 5½ years. Other illnesses and comorbidities were determined using *ICD-9* codes, including infant bronchiolitis, which was defined by the presence of *ICD-9* codes 466.1 and/or 480.1 during the first year of life or after the first year of life if the appropriate *ICD-9* diagnosis was present on a day when an *ICD-9* diagnosis for asthma was not also submitted. Chronic comorbidities, including congenital heart, lung, and airway abnormalities, cystic fibrosis, diabetes, chronic kidney disease, neuromuscular disorders, and immunodeficient states, were determined by *ICD-9* codes submitted during the first 3½ years of life.

To assess use of outpatient health care, the number of outpatient visits children with asthma made for any reason was determined. Also, outpatient visits for asthma care were identified, and pharmacy claims data were used to determine filling of inhaled corticosteroid (ICS) prescriptions from the ages of 4½ to 5½ years (this age range was chosen to use the oldest available 1-year interval for each child to minimize misclassification of childhood postviral wheezing as asthma).

To measure asthma morbidity, yearly rates from the ages of 4½ to 5½ years of episodes of asthma care (*ICD-9* code, 493) that occurred in the ED or that required observation admission or inpatient hospital care were determined. Prescriptions for rescue medications (oral corticosteroids and short-acting β -agonists) were determined from pharmacy claims data. The protocol was approved by the institutional review boards of Vanderbilt University and the Tennessee Department of Health. Informed consent of study participants was waived because this was deidentified administrative data.

Asthma prevalence and morbidity were presented as frequency and proportion, mean and standard deviation, or median and interquartile range as appropriate. Asthma morbidity variables were compared by residence status using the Kruskal-Wallis test for continuous measures and the χ^2 test for proportions. The main independent variable was child residence (urban, suburban, or rural, as defined above). Outcomes included the prevalence of asthma from the ages of 4 to 5½ by residence and asthma morbidity as measured by acute care visits for asthma and asthma rescue medication use. Odds ratios (ORs) were calculated to assess the association of rural vs urban residence with the outcome of asthma diagnosis at the ages of 4 to 5½ years using a multivariable logistic regression model. Separate multivariable logistic regression models were used to calculate ORs for the association of child residence with the outcomes of allergic rhinitis, eczema, and use of any ICS, oral corticosteroid, or short-acting β -agonist. Separate multivariable Poisson regression analyses were performed to calculate risk ratios for the association of child residence status and the number of outpatient visits, ED visits, asthma-related inpatient and 23-hour admissions, ICS prescriptions, oral corticosteroid courses, and short-acting β -agonists per child. The Huber-White robust sandwich estimator was used for estimating standard errors.¹⁹ Child and maternal covariates included in adjusted statistical models were birth weight, sex, child race/ethnicity, number of siblings, history of bronchiolitis, presence of chronic conditions (listed above) that might affect measures of asthma severity, maternal smoking during pregnancy, maternal asthma (determined as discussed above), and maternal education level. Statistical analysis was performed using SAS statistical software, version 9.1 (SAS Institute Inc, Cary, North Carolina), and R version 2.10.1 (<http://www.R-project.org>).

RESULTS

A total of 117,080 children met eligibility requirements and were studied. Forty-five percent were urban, 23% suburban, and 33% rural. Key demographic features of this cohort are

presented in Table 1. Most of the urban group was African American (69%), whereas most of the suburban and rural groups were white (73% of the suburban group and 81% of the rural group). Urban children were somewhat more likely to have low birth weight. Rural children were more likely to have a history of bronchiolitis, and their mothers were more likely to smoke and have a history of asthma. The prevalence of 1 or more chronic health conditions, including congenital disorders of the heart and lungs, was similar in the 3 groups.

The prevalence of asthma and allergic rhinitis was higher in rural areas. Eleven percent of urban, 12% of suburban, and 13% of rural children met study criteria for asthma diagnosis from the ages of 4 to 5½ years ($P < .001$), whereas 9% of urban, 11% of suburban, and 13% of rural children met study criteria for allergic rhinitis diagnosis from the ages of 3½ to 5½ years ($P < .001$). The prevalence of atopic dermatitis, defined as 2 or more ICD-9 diagnoses from the ages of 3½ to 5½ years, was low (1%) in all 3 groups.

Among the subgroup of children with prevalent asthma, several measures of outpatient health care use were examined (Table 2). From the ages of 3½ to 5½ years, rural and suburban children with asthma made a greater number of total outpatient visits for any reason compared with urban children. Rural and suburban children had a similar rate of making 1 or more outpatient asthma visits from the ages of 4½ to 5½ years compared with urban children and had a somewhat greater number of visits per child. In contrast,

urban children were somewhat more likely to have been prescribed an ICS from the ages of 4½ to 5½ years (31% of rural children, 32% of suburban children, and 35% of urban children; $P < .001$). Notably, among those children who were prescribed an ICS, each child only filled a median of 2 (urban children) or 1 (other children) 1-month prescription per year.

There were several differences in measures of asthma morbidity by urban-rural residence (Table 2 and Fig 1). Rural and suburban children with asthma had a lower yearly rate of making 1 or more ED visits for asthma compared with urban children. However, rural children had similar yearly rates of inpatient and observation asthma admissions and had a larger number of asthma observation admissions per child from the ages of 4½ to 5½ years compared with urban children.

All 3 groups had a similar yearly rate of filling 1 or more courses of oral rescue corticosteroids (approximately 40% of children in all 3 groups) and filled a similar number of prescriptions per child. The 3 groups also had a similar yearly rate of filling 1 or more short-acting β -agonists (approximately 75% in each group) and filled a similar number of prescriptions per child.

In multivariable analysis (Table 3) controlling for demographic variables specific to the child (birth weight, sex, race, presence of chronic health conditions, and history of bronchiolitis) and to the mother (maternal smoking, education, and history of asthma), increased asthma prevalence in rural and suburban children persisted, as did increased allergic

Table 1. Demographic Characteristics of a Birth Cohort of 117,080 Children Born From 1995 to 2000 and Enrolled in Tennessee Medicaid Who Were Followed up Through the Sixth Year of Life^a

Characteristic	Urban (n = 52,168)	Suburban (n = 26,493)	Rural (n = 38,317)	P value ^b
Male sex	26,608 (51)	13,447 (51)	19,830 (52)	.04
Child race				<.001
White	11,847 (23)	19,269 (73)	31,219 (81)	
African American	36,213 (69)	5,507 (21)	4,892 (13)	
Hispanic	1,268 (2)	458 (2)	718 (2)	
Other	2,840 (5)	1,259 (5)	1,488 (4)	
Gestational age, mean (SD), wk	38.4 (2.9)	38.7 (2.6)	38.8 (2.6)	<.001
Birth weight <2,500 g	7,240 (14)	2,969 (11)	4,053 (11)	<.001
History of ≥ 1 chronic medical conditions other than asthma ^c	3,248 (6)	1,859 (7)	2,442 (6)	<.001
History of bronchiolitis before 1 year of age	9,057 (17)	5,317 (20)	8,527 (22)	<.001
Maternal cigarettes per day during pregnancy				<.001
Nonsmoker	43,225 (83)	17,261 (66)	24,707 (65)	
<10	2,713 (5)	1,939 (7)	2,560 (7)	
≥ 10	5,961 (11)	7,063 (27)	10,787 (28)	
Maternal education				<.001
<12 years	23,173 (45)	11,287 (43)	17,065 (45)	
12 years	21,699 (42)	11,935 (45)	17,680 (46)	
>12 years	7,191 (14)	3,242 (12)	3,493 (9)	
Maternal asthma	2,199 (6)	1,101 (8)	1,759 (9)	<.001

^a Unless otherwise noted, data are presented as number (percentage).

^b The χ^2 test was used for comparing proportions and Kruskal-Wallis test for comparing continuous variables. Comparisons were among the 3 residence groups.

^c Comorbid conditions in addition to asthma, including congenital heart, lung, and airway abnormalities; cystic fibrosis; diabetes; neuromuscular disorders; chronic kidney disease; immunodeficient states.

Table 2. Measures of Outpatient and Inpatient Health Care Use and Asthma Morbidity Among 13,775 Medicaid-Enrolled Children With Asthma by Urban-Rural Residence^a

Measure	Children with asthma, N = 13,775			P value ^b
	Urban (n = 5,639)	Suburban (n = 3,308)	Rural (n = 4,818)	
Mean (SD) outpatient visits per asthmatic child for any reason (age 3½–5½ years)	11.0 (8.2)	14.6 (9.4)	15.7 (9.9)	<.001
Children making ≥1 outpatient asthma visits per year, %	40	39	41	.52
Of those making ≥1 outpatient asthma visits, mean (SD) No. of visits per child per year	2.0 (1.5)	2.1 (1.7)	2.2 (1.9)	<.001
Children filling ≥1 ICS prescriptions per year, %	35	32	31	<.001
Of those filling ≥1 ICS prescriptions, median No. (IQR) filled per child per year	2.0 (1.0–3.0)	1.0 (1.0–3.0)	1.0 (1.0–3.0)	.05
Children making ≥1 ED visits for asthma per year, %	29	23	20	<.001
Among those making ≥1 ED asthma visits, mean (SD) No. of visits per child per year	1.4 (1.0)	1.4 (0.9)	1.4 (0.9)	.07
Children having ≥1 23-hour observation admissions for asthma per year, %	4	3	4	.02
Among those having ≥1 23-hour observation admissions for asthma, median No. (IQR) of admissions per child per year	2.0 (1.0–3.0)	2.0 (1.0–4.0)	3.0 (2.0–3.0)	<.001
Children having ≥1 inpatient admissions for asthma per year, %	6	5	6	.02
Among those having ≥1 inpatient admissions for asthma, mean (SD) No. of admissions per child per year	1.2 (0.5)	1.1 (0.6)	1.1 (0.4)	.13
Children having ≥1 ED, 23-hour observation, or inpatient visits for asthma per year, %	30	25	23	<.001
Children who filled ≥1 oral corticosteroid courses per year, %	41	41	43	.03
Among those who filled ≥1 oral corticosteroid courses, mean (SD) No. of courses per child per year	1.1 (1.0)	1.0 (1.0)	1.1 (1.1)	.10
Children who filled ≥1 short-acting β-agonist prescriptions per year, %	79	77	76	.006
Among those who filled ≥1 short-acting β-agonist prescriptions, mean No. (IQR) of fills per child per year	2.0 (1.0–3.0)	2.0 (1.0–3.0)	2.0 (1.0–3.0)	<.001

Abbreviations: ED, emergency department; ICS, inhaled corticosteroid; IQR, interquartile range.

^a Data were determined for the 1-year age interval from 4½ to 5½ years of age, except as indicated.

^b The χ^2 test was used for comparing proportions and Kruskal-Wallis test for comparing continuous variables. Comparisons were among the 3 residence groups.

rhinitis in rural but not in suburban children, compared with urban as referent. Rural children, but not suburban children, had a marginally statistically significant decreased odds of receiving 1 or more ICSs prescription (rural vs urban: OR, 0.87; 95% confidence interval, 0.77–0.99). Decreased ED visits among rural but not suburban children vs urban children persisted in multivariable analysis. There was no significant difference by residence in asthma-related inpatient or 23-hour observation admissions or in use of short-acting β-agonists or oral corticosteroids.

DISCUSSION

Residents of the rural United States face a wide variety of economic and health care disparities that might be expected to affect asthma outcomes, but there are few studies conducted in the United States comparing either asthma prevalence or morbidity in rural vs urban populations.^{13–14,20} Of these, one report used state surveillance data on asthma ED visits and therefore offers no data on prevalence,¹⁴ and another was a non-peer-reviewed work group report.²⁰ This report²⁰ analyzed Behavioral Risk Factor Surveillance System

data and found a national prevalence of self-reported asthma in urban areas of 12% vs 11% in rural areas ($N = 264,684$, $P < .001$). The present study is the first to use administrative data to compare urban and rural asthma prevalence and morbidity outcomes in a large, statewide, population-based cohort of Medicaid-enrolled children. Because 32.5% of urban children (<18 years old) and 40.7% of rural children in Tennessee were enrolled in Medicaid as of 2008–2009, the study population represents a large portion of children in the state and is likely to be similarly representative of the overall urban and rural pediatric populations in Tennessee.²¹ Compared with urban children, rural children in this Medicaid cohort have increased asthma and allergic rhinitis prevalence, similar use of asthma rescue medications, similar asthma hospitalization rates, and increased receipt of health care in the outpatient setting, underscoring the need for improved understanding of asthma management and care patterns among Medicaid-enrolled rural children to improve outcomes for this high-risk population of children.

Several features of the rural cohort might serve as a basis for further study regarding optimal interventions to benefit

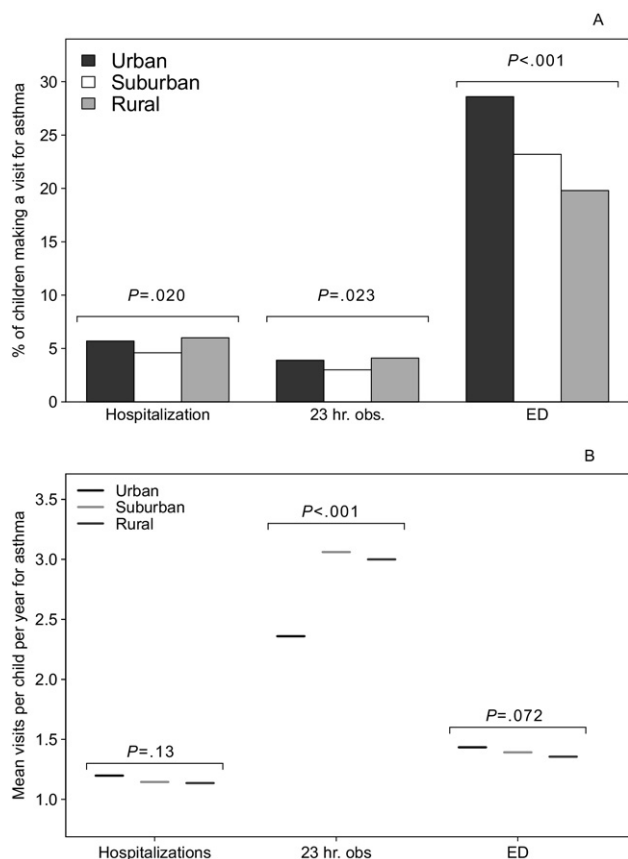


Figure 1. Yearly episodes of acute care for asthma among 13,775 Medicaid-enrolled children with asthma by urban-rural residence (ages 4½–5½ years). A, Percentage of asthmatic children making 1 or more of each visit type for asthma-related care per year. B, Number of visits per child among those making 1 or more visit.

rural asthmatic children. Rural children were more likely to have smoking mothers and to have a history of bronchiolitis, both of which are associated with increased asthma risk,^{22–23} and so efforts to reduce secondhand smoke exposure and to reduce winter viral infection transmission might have a greater impact on asthma among rural children. Rural children had a higher prevalence of allergic rhinitis, and so measures to treat this condition and reduce allergen exposure may help to improve asthma control in this population. The percentage of asthmatic children filling an ICS prescription per year (which only slightly exceeded the percentage of asthmatic children who made an ED visit for asthma per year) was low, and among those who filled 1 or more prescriptions, who should therefore be taking the medication continuously, rural children filled a median of 1 month and urban children a median of 2 months of prescriptions in a 1-year period. This finding suggests that achieving improved adherence to ICSs is likely to improve asthma control in this population, regardless of residence. Finally, rural children made a greater number of outpatient visits for any reason and for asthma and

made fewer ED asthma visits compared with urban children. This difference in health care provision suggests that, in rural areas, interventions to reduce asthma morbidity might be most effectively targeted to the primary care realm.

The decreased number of asthma ED visits by rural children might have several explanations. First, this might represent a decreased frequency and/or severity of asthma exacerbations among rural children. However, the similar rate of asthma hospitalization for urban and rural children (implying that rural children are more likely to be hospitalized each time they present to the ED for asthma) argues against this (although it could be explained by a lower level of comfort managing asthma among rural EDs, leading to a higher admission rate), as does the similar pattern in rescue medication use by residence. A second explanation for decreased asthma ED visits among rural vs urban children is that urban families may have a lower threshold to present to the ED for asthma, given closer proximity and greater convenience. Indeed, the lower numbers of outpatient visits for any reason and for asthma among urban vs rural children suggest that for urban children the ED may partially supplant the role of the primary care physician, as has been observed in previous studies.^{24,25} In contrast, rural children may be less likely to present to the ED for asthma unless truly sick, given a greater distance to travel.

We separated children into 3 groups, based on the Office of Management and Budget system of SMSAs, which for ease of understanding we termed *urban*, *suburban*, and *rural*. The urban children live in urban central counties within SMSAs, the suburban children in noncentral (but, by definition, economically interrelated) counties within SMSAs, and the rural children in all other counties. As can be readily observed from Table 1, the demographic features of the suburban cohort are similar to those of the rural cohort. In general, Tennessee's cities are medium sized, and counties surrounding urban counties tend to be rural. The suburban group, therefore, should be thought of as a rural population that has improved access to metropolitan resources compared with the rural group, which represents a group economically and geographically separate from the nearest cities. One related issue is that truly suburban (ie, more advantaged) neighborhoods are located within the urban central counties and therefore are included under the urban heading. However, because this is a Medicaid population, it is unlikely that many more highly advantaged children are included in the urban cohort, and therefore the observed urban asthma prevalence is unlikely to be falsely low. Other commonly used rural-urban classification systems, including urban influence codes and rural urban continuum codes, similarly divide populations at the county level. Systems that divide at the level of the census tract (eg, rural urban commuting area) exist but require the individual's home address, whereas we retained only zip codes in our data set. Dividing children by zip code would require cross-referencing with an existing classification scheme, likely one of the county-based systems (ie, zip codes would be used to determine county of residence, which would be the ultimate

Table 3. Asthma Prevalence, Outpatient Health Care Use, and Asthma Morbidity Among Medicaid-Enrolled Children in Tennessee^a

Outcome	Suburban (referent: urban)	Rural (referent: urban)
Atopic disease prevalences		
Asthma diagnosis ^b	1.22 (1.14–1.30)	1.16 (1.09–1.24)
Allergic rhinitis, ages 3½–5½ ^b	0.96 (0.89–1.04)	1.14 (1.06–1.22)
Atopic dermatitis, ages 3½–5½ ^b	1.13 (0.90–1.43)	1.07 (0.85–1.34)
Outpatient health care use		
Outpatient asthma visits per child ^c	1.07 (0.96–1.20)	1.15 (1.03–1.28)
ICS prescriptions, any use vs no use ^b	0.92 (0.81–1.05)	0.87 (0.77–0.99)
ICS prescriptions per child filling ≥ prescription ^c	0.86 (0.73–1.00)	0.77 (0.65–0.90)
Asthma acute care and rescue medication use		
Rescue steroid courses, any use vs no use ^b	1.00 (0.88–1.14)	1.09 (0.96–1.23)
Short-acting β-agonists, any use vs no use, ages 3½–5½ years ^b	0.89 (0.77–1.04)	0.88 (0.76–1.01)
ED visits for asthma per child ^c	0.93 (0.82–1.07)	0.78 (0.68–0.89)
23-Hour observation admissions for asthma per child ^c	1.12 (0.70–1.80)	1.32 (0.97–1.83)
Inpatient hospitalizations for asthma per child ^c	0.85 (0.64–1.13)	1.00 (0.78–1.29)
No. of oral corticosteroid courses per child ^c	0.99 (0.93–1.05)	1.02 (0.96–1.08)
No. of short-acting β-agonist inhalers filled per child ^c	0.97 (0.91–1.03)	0.96 (0.89–1.02)

Abbreviations: ED, emergency department; ICS, inhaled corticosteroid.

^a Outcomes are measured from the ages of 4½ to 5½ years unless otherwise specified.

^b Multiple logistic regression models were used, controlling for child birth weight, sex, race, chronic medical conditions, history of bronchiolitis, maternal smoking, maternal education, and maternal history of asthma, to calculate adjusted odds ratios (95% confidence intervals).

^c Poisson regression models were used to estimate risk ratios (95% confidence intervals) controlling for the covariates mentioned above.

determiner of urbanicity, and so no additional detail would be gained).²⁶

One limitation of this study is that, like all administrative database studies, it relies on the completeness of the submitted data. For example, it seems unlikely that the observed prevalence of atopic dermatitis (1% of urban, suburban, and rural children with ≥2 ICD-9 diagnoses from the ages of 3½ to 5½ years) captures all children of this age with the condition; perhaps this condition is undercoded when a child presents with several issues, or perhaps children with minimally symptomatic atopic dermatitis only present for their well visits and are only coded as a well visit by their pediatrician.

However, this study has a number of strengths. First, the use of a Medicaid administrative database design allows us to capture a very large, statewide, population-based cohort of vulnerable children, with adequate representation of patient subgroups. Second, there is little published information about asthma in the rural United States, and this study presents some of the first evidence for significant asthma prevalence, morbidity, and differential health care use practices in a rural vs urban US population. Future work should expand our understanding of asthma care and morbidity in the rural United States and identify appropriate interventions that are likely to differ from those for urban populations to improve outcomes in this disadvantaged population.

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- Requests for reprints should be addressed to:*
Tina V. Hartert, MD, MPH
Vanderbilt University School of Medicine
Center for Health Services Research, 6107 MCE
Nashville, TN 37232-8300
E-mail: tina.hartert@vanderbilt.edu
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