



Scan for Author
Audio Interview

Out-of-Pocket Medication Costs and Use of Medications and Health Care Services Among Children With Asthma

Pinar Karaca-Mandic, PhD

Anupam B. Jena, MD, PhD

Geoffrey F. Joyce, PhD

Dana P. Goldman, PhD

IN RECENT YEARS, PRIVATE HEALTH plans have attempted to contain medication costs by shifting costs toward patients.^{1,2} Among adults, greater patient medication cost sharing has been associated with reduced medication use¹⁻⁴ and increases in emergency department (ED) visits and hospitalizations.⁵⁻⁸ Similar data are limited among children,^{9,10} although nearly 45 million children in the United States are privately insured.¹¹ Barriers to health care clearly exist for uninsured children,¹² but the association of greater medication cost sharing with the health care decisions insured families make for their children has been overlooked.

We examined how prescription medication cost sharing among privately insured families was associated with medication and other health care utilization by children in those families. Since greater cost sharing may be most relevant for children with chronic disease,^{1,13} we focused on asthma, the leading childhood chronic disease. Childhood asthma is associated with avoidable morbidity and mortality and lower quality of life,¹⁴ and medication underuse is common.¹⁵

For editorial comment see p 1316.

Author Video Interview available at www.jama.com.

Context Health plans have implemented policies to restrain prescription medication spending by shifting costs toward patients. It is unknown how these policies have affected children with chronic illness.

Objective To analyze the association of medication cost sharing with medication and hospital services utilization among children with asthma, the most prevalent chronic disease of childhood.

Design, Setting, and Patients Retrospective study of insurance claims for 8834 US children with asthma who initiated asthma control therapy between 1997 and 2007. Using variation in out-of-pocket costs for a fixed "basket" of asthma medications across 37 employers, we estimated multivariate models of asthma medication use, asthma-related hospitalization, and emergency department (ED) visits with respect to out-of-pocket costs and child and family characteristics.

Main Outcome Measures Asthma medication use, asthma-related hospitalizations, and ED visits during 1-year follow-up.

Results The mean annual out-of-pocket asthma medication cost was \$154 (95% CI, \$152-\$156) among children aged 5 to 18 years and \$151 (95% CI, \$148-\$153) among those younger than 5 years. Among 5913 children aged 5 to 18 years, filled asthma prescriptions covered a mean of 40.9% of days (95% CI, 40.2%-41.5%). During 1-year follow-up, 121 children (2.1%) had an asthma-related hospitalization and 220 (3.7%) had an ED visit. Among 2921 children younger than 5 years, mean medication use was 46.2% of days (95% CI, 45.2%-47.1%); 136 children (4.7%) had an asthma-related hospitalization and 231 (7.9%) had an ED visit. An increase in out-of-pocket medication costs from the 25th to the 75th percentile was associated with a reduction in adjusted medication use among children aged 5 to 18 years (41.7% [95% CI, 40.7%-42.7%] vs 40.3% [95% CI, 39.4%-41.3%] of days; $P=.02$) but no change among younger children. Adjusted rates of asthma-related hospitalization were higher for children aged 5 to 18 years in the top quartile of out-of-pocket costs (2.4 [95% CI, 1.9-2.8] hospitalizations per 100 children vs 1.7 [95% CI, 1.3-2.1] per 100 in bottom quartile; $P=.004$) but not for younger children. Annual adjusted rates of ED use did not vary across out-of-pocket quartiles for either age group.

Conclusion Greater cost sharing for asthma medications was associated with a slight reduction in medication use and higher rates of asthma hospitalization among children aged 5 years or older.

JAMA. 2012;307(12):1284-1291

www.jama.com

Using longitudinal private insurance data, we identified children with asthma requiring long-acting asthma

control therapy. We analyzed the association of out-of-pocket asthma medication cost with medication use and

Author Affiliations: Division of Health Policy and Management, School of Public Health, University of Minnesota, Minneapolis (Dr Karaca-Mandic); Department of Medicine, Massachusetts General Hospital, Harvard Medical School, Boston (Dr Jena); Leonard D. Schaeffer Center for Health Policy and Economics,

University of Southern California, Los Angeles (Drs Joyce and Goldman).

Corresponding Author: Anupam B. Jena, MD, PhD, Department of Medicine, Massachusetts General Hospital, Wang Ambulatory Care Center, 15 Parkman St, Boston, MA 02114 (jena.anupam@mgh.harvard.edu).

asthma-related hospitalizations and ED visits. We hypothesized that greater out-of-pocket costs would be associated with reductions in asthma medication use and increases in other asthma-related health care services.

METHODS

We obtained data on pharmacy and medical claims from 1997 through 2008 for 37 geographically diverse US employers. These data, obtained from a benefits consulting firm, have been used to explore the association of pharmacy benefit design with medication use by chronically ill individuals.^{1,2,6,16,17} Each employer offered 1 or more health plans to its active or retired employees and their dependents. The claims data contained information on the use of all medications (including those purchased as 90-day or mail-order prescriptions) and medical services for the insured population. Because the data were deidentified, the study was exempted from human subjects review by the institutional review boards of the University of Southern California and University of Minnesota.

We identified children with asthma for whom therapy was initiated with a long-acting asthma control medication (inhaled corticosteroids [ICSs], long-acting β_2 -agonists [LABAs], leukotriene receptor antagonists, combined ICS-LABA formulations, methylxanthines, cromolyn sodium, or immunomodulators) between 1997 and 2007. Although asthma control therapy is intended to be taken daily and year-round by children with persistent asthma, existing guidelines and evidence also support use as needed (eg, seasonally).^{14,18} We focused on children requiring control therapy since medication adherence is important to minimizing disease exacerbations¹⁴ and utilization may be related to medication cost sharing. We restricted our analysis to incident cases of children initiating therapy in an attempt to study children with newly diagnosed persistent asthma.¹⁹

We first identified all beneficiaries younger than 18 years with asthma

based on 2 or more medical claims with an *International Classification of Diseases, Ninth Revision (ICD-9)* diagnosis code for asthma (493.XX) or 2 or more prescriptions for an asthma medication (n=60 735). Of these children, 41 782 had at least 1 claim filled for an asthma control medication. Following prior work, we identified children who had control therapy initiated by excluding those with a pharmacy claim for a control medication in the prior 6 months (n=24 592 remaining).¹⁹ Within this group, we included only children who were continuously enrolled for at least 1 year after initiation of therapy and for whom a prescription was refilled for an asthma control medication at least once beyond 30 days after initiation (n=8834).

Our sample selection was intended to identify children with newly diagnosed persistent asthma who were starting control therapy. Some children may have episodic symptoms for which they are prescribed daily control therapy only seasonally or during periods of exacerbation.^{14,18} Some of these children may be included in our sample if they had no exacerbations requiring control therapy in the prior 6-month period. As a sensitivity analysis, we restricted our sample to include a 12-month period without prior asthma control therapy (n=6404) to create a more homogenous sample of children with presumably newly diagnosed persistent asthma requiring control therapy.

Asthma Medication Use

We followed up the children in our sample for 365 days after the defined date of initiation of control therapy. We defined medication use as the percentage of 365 days in which control therapy was supplied. For example, if a child had 6 prescriptions filled, each providing a 30-day supply, use was defined as 50% ($180/365=49.3\%$). For children using multiple medications (eg, an ICS and a LABA), a child was considered to use control therapy in a given period if a prescription was filled for either of the 2 medications. In quan-

tifying medication use, not all children in our sample may have been expected to use control therapy year-round but, rather, for a short period after being prescribed therapy. For these children, medication use measured over a 365-day period would be inappropriate. As a sensitivity analysis, we measured medication use in the 90 days following initiation of control therapy to account for children whose expected course of control therapy may have been shorter. We also accounted for children who may have started therapy because of seasonal symptoms by studying children first initiating therapy during the pollen season (defined as April-September). In the seasonal analysis, medication use was defined as the percentage of days in the season in which control therapy was supplied (after initiation).

Asthma-Related Health Services

Asthma-related hospitalizations and ED visits were identified from medical claims using the primary ICD-9 diagnosis code for asthma. Emergency department visits included those that resulted in patient discharge from the ED as well as those resulting in hospitalization. For asthma-related hospitalizations, total expenditures were calculated as the sum of payment by the health plan and beneficiary and included facility payments as well as professional service fees.

Out-of-Pocket

Asthma Medication Costs

Following prior work,^{1,2,17} we computed the mean out-of-pocket cost within a plan of a representative, fixed "basket" of asthma control medications. Our intent was to capture the out-of-pocket prices faced by patients in different plans. We computed out-of-pocket costs for a basket of medications for 2 reasons. First, it is difficult to summarize a plan's out-of-pocket cost of a specific medication when tiered formularies, utilization requirements (such as prior authorizations and step-therapy limitations), and in-network and mail-order discounts are com-

mon. Second, costs estimated from all out-of-pocket medication expenditures, rather than from a fixed basket of medications, may misrepresent the out-of-pocket prices faced by patients. For example, consider 2 health plans: the first charges a \$5 co-payment for medications 1 and 2 and the second charges a \$5 co-payment for medication 1 and a \$15 co-payment for medication 2. If all patients in the second plan chose medication 1 because it is cheaper, estimated mean out-of-pocket expenditures would be identical across plans despite plan 1 having a more generous pharmacy benefit.

For each plan p in a given year, we calculated the mean annual out-of-pocket cost of a 30-day prescription for a medication in class j (eg, ICS, LABA) among all adults and children with asthma, Avg_{pj} . Both children and adults were used to compute out-of-pocket costs because pharmacy benefits do not depend on whether a medication is dispensed to a child or an adult. We applied these plan- and class-specific out-of-pocket costs to a representative basket of medications, determined on the basis of usage by all children in our final sample. Specifically, we computed mean annual out-of-pocket costs per child for the representative basket of asthma medications in each plan ($PlanRx_p$) and year by weighting plan- and class-specific mean out-of-pocket costs (Avg_{pj}) with the average number of 30-day prescriptions for each class per child per year in our final sample:

$$PlanRx_p = \sum_{j=1}^{No. of Classes} Avg_{pj} * \frac{Prescriptions_j}{No. of Children}$$

The basket of medications was fixed across individuals, allowing for a comparison of the out-of-pocket cost of purchasing the basket across different plans (146 plan-years). All dollar amounts were converted to 2010 dollars.

Analysis

We estimated the association between out-of-pocket asthma medication cost and medication use with a multivariate

generalized linear model with a logarithmic link function. We adjusted for child and family characteristics and the mean coinsurance rate for nonmedication services.² Child characteristics included age, sex, an indicator for whether therapy was initiated during pollen season, an indicator for allergic rhinitis, and the number of comorbidities besides asthma and allergic rhinitis. Disease severity was adjusted for by including counts of asthma-related hospitalizations and ED visits in the 6 months prior to initiating asthma control therapy. Family characteristics included the number of adults in the family and their mean age, the number of additional children insured under the same policy, indicator variables for parental asthma and other comorbidities, and sociodemographic characteristics of the family’s zip code drawn from the US Census (age distribution of population; percentage self-reported white, black, or other; percentage self-reported Hispanic; percentage with college degree among population aged <65 years; median income among families with children; and rural/urban composition).^{1,2} Initial options for race were defined by the US Census; however, we defined an “other” category for individuals who did not self-report being white or black/African American. The utilization model was estimated separately for children aged 5 years or older and those younger than 5 years based on greater severity and different treatment guidelines among infants and toddlers with asthma.^{14,20}

We estimated the association between out-of-pocket asthma medication cost and asthma-related hospitalizations and ED visits in the 365 days following initiation of asthma control therapy. Asthma-related hospitalizations and ED visits were defined as binary variables, although our results were robust to defining both as count variables. For each outcome, we estimated a multivariate logistic regression model adjusting for child and family characteristics, disease severity, and mean coinsurance for nonmedication services. We also estimated the association of out-of-pocket medication costs with total spending (patient + health plan) on asthma-

related hospitalizations. Because hospital expenditures were not normally distributed, we estimated the association with expenditures using a 2-part model²¹ that combined estimates of the probability of hospitalization from the logistic model with a generalized linear model estimating inpatient spending among children with at least 1 asthma-related hospitalization. Confidence intervals in the expenditure model were computed by 1000-sample bootstrap. All models included fixed effects for the year of control therapy initiation and Census region and were clustered at the employer-year level. Nonsignificant variables were not omitted from the models.

In addition to sensitivity analyses addressing intermittently prescribed asthma control therapy, we explored whether the association of out-of-pocket asthma medication costs with use of health services was confounded by unobserved child or family characteristics such as overall health or underlying propensity to use services. Specifically, we estimated the association between out-of-pocket asthma medication costs and non-asthma-related hospitalizations, hypothesizing that greater out-of-pocket medication costs should not be associated with greater non-asthma-related hospitalizations unless selection bias were present. Moreover, because out-of-pocket asthma medication costs varied at the plan-year level, we assessed whether our results were robust to a hierarchical modeling approach with nesting at the employer and plan levels. Finally, we conducted a residual confounding analysis to assess the extent of potential bias (eg, due to unobserved asthma severity among patients in plans with high out-of-pocket costs) in our estimates.²² We assumed a binary unmeasured confounder that was patient specific and independent of measured confounders and investigated the degree of confounding needed to eliminate the estimated association between out-of-pocket asthma medication costs and hospitalizations. Stata software, version 11.2 (Stata Corp) was used for statistical analyses and 95% CIs reflect 0.025 in each tail or $P < .05$.

RESULTS

Our sample included 8834 children, 2921 of whom were younger than 5 years (mean age, 2.5 years) and 5913 of whom were aged 5 to 18 years (mean age, 9.7 years) (TABLE 1). The majority of children were male (n=5290 [59.9% of full sample]). A minority of children had concurrent diagnoses of allergic rhinitis (n=1177 [13.3%]). Chronic conditions other than asthma or allergic rhinitis were infrequent. For 1436 children (16.3%) in our study, at least 1 other adult family member had asthma. Among both age groups, the most commonly used asthma medications were ICSs (86.3% of children aged <5 years and 75.4% of children aged 5-18 years), followed closely by leukotriene receptor antagonists (TABLE 2). Combined corticosteroid/LABA preparations were common among the older age group (n=2004 [33.9%]). A substantial proportion of children in both age groups used more than 1 asthma medication (61.8% of children aged <5 years and 60.2% of children aged 5-18 years).

Across plans, the mean out-of-pocket cost of the standardized basket of asthma medications per year was \$154 (95% CI, \$152-\$156) among those aged 5 to 18 years (TABLE 3) and \$151 (95% CI, \$148-\$153) among those younger than 5 years (eTable 1 available at <http://www.jama.com>). Mean use of asthma control therapy was low in both age groups. Among children aged 5 to 18 years, filled asthma prescriptions covered a mean of 40.9% (95% CI, 40.2%-41.5%) of days; among children younger than 5 years, prescriptions covered 46.2% (95% CI, 45.2%-47.1%) of days (eTable 1). Although child and family characteristics did not vary across plans with differing out-of-pocket asthma medication costs (Table 3), unadjusted mean use of asthma control therapy decreased slightly with higher out-of-pocket medication costs. For example, among children aged 5 to 18 years in the highest quartile of out-of-pocket asthma medication costs, prescriptions covered 41.3% of days (95% CI, 40.0%-42.6%) vs 42.2% (95% CI, 40.9%-43.6%) for children in the lowest quartile (P=.34). Annual, un-

adjusted mean rates of asthma-related hospitalization were greater for children in the highest quartile vs the lowest quartile (2.7% vs 1.4%; P=.01). In contrast, unadjusted mean rates of asthma-related ED visits were lower for children in the highest quartile vs the lowest (3.9% vs 4.3%; P=.53). Annual unadjusted mean rates of asthma-related ED visits and hospitalization were greater among children younger than 5

years (7.9% [n=231] and 4.7% [n=136], respectively) (eTable 1) vs children aged 5 to 18 years (3.7% [n=220] and 2.1% [n=121], respectively) (Table 3).

TABLE 4 shows factors associated with asthma medication use from multivariate analysis. Among children aged 5 to 18 years, mean annual out-of-pocket asthma medication costs were negatively associated with medication use over the 365-day follow-up period

Table 1. Characteristics of Children With Asthma and Their Families

Characteristics	Full Sample (N = 8834)	Aged <5 Years (n = 2921)	Aged 5-18 Years (n = 5913)
Child characteristics			
Age, mean (SD), y	7.3 (4.5)	2.5 (1.2)	9.7 (3.6)
Male, No. (%)	5290 (59.9)	1825 (62.5)	3465 (58.6)
Allergic rhinitis, No. (%)	1177 (13.3)	379 (13.0)	798 (13.5)
No. of chronic conditions in addition to asthma/allergic rhinitis, median (range)	0 (0-3)	0 (0-3)	0 (0-3)
Family characteristics			
No. of adults per child, mean (SD)	1.9 (0.5)	1.8 (0.4)	1.9 (0.5)
Age of adults, mean (SD), y	38.5 (6.2)	35.3 (5.3)	40.1 (6.0)
No. of additional children insured, mean (SD)	1.1 (1.0)	0.9 (0.9)	1.2 (1.0)
Location in United States, No. (%)			
Northeast	1910 (21.6)	594 (20.3)	1316 (22.3)
Midwest	1577 (17.9)	444 (15.2)	1133 (19.2)
West	1226 (13.9)	384 (13.1)	842 (14.2)
South	4121 (46.7)	1499 (51.3)	2622 (44.3)
At least 1 adult with asthma, No. (%)	1436 (16.3)	478 (16.4)	958 (16.2)
Characteristics of child's zip code, mean (SD), %^a			
Aged <18 y	25.9 (2.5)	25.8 (2.6)	25.9 (2.5)
Aged ≥65 y	11.7 (3.5)	11.6 (3.6)	11.8 (3.4)
Urban residence	80.4 (19.4)	81.4 (19.4)	79.9 (19.4)
White	78.9 (13.1)	77.7 (13.3)	79.4 (12.9)
Black	10.5 (10.6)	11.5 (11.2)	10.0 (10.3)
Hispanic	11.2 (12.1)	11.8 (12.5)	10.9 (11.9)
Aged <65 y with more than high school education	25.7 (8.5)	25.9 (8.7)	25.5 (8.4)
Annual family income, median (range), \$	55 469 (24 547-135 244)	55 273 (24 547-135 244)	55 565 (24 693-120 307)

^aCharacteristics of child's zip code are obtained from US Census data at the 3-digit zip code level.

Table 2. Asthma Medication Use

Medication	No. (%)	
	Aged <5 Years (n = 2921)	Aged 5-18 Years (n = 5913)
Inhaled corticosteroids	2522 (86.3)	4458 (75.4)
Leukotriene receptor antagonists	2053 (70.3)	3695 (62.5)
Long-acting β ₂ -agonists	78 (2.7)	348 (5.9)
Combination inhaled corticosteroids/long-acting β ₂ -agonists	266 (9.1)	2004 (33.9)
Cromolyn sodium/nedocromil	177 (6.1)	269 (4.6)
Methylxanthines	3 (0.1)	30 (0.5)
Immunomodulators	1 (0.1)	11 (0.2)
Use of >1 medication	1805 (61.8)	3560 (60.2)

Table 3. Child and Family Characteristics and Medication and Hospital Utilization by Quartile of Out-of-Pocket Cost for Asthma Medications Among Children Aged 5-18 Years^a

Characteristics	Full Sample (n = 5913)	Quartile 1 (n = 1436)	Quartile 2 (n = 1502)	Quartile 3 (n = 1478)	Quartile 4 (n = 1497)
Child and family characteristics					
Age, mean (SD), y	9.7 (3.6)	9.6 (3.6)	9.7 (3.5)	9.6 (3.5)	9.7 (3.6)
Male, No. (%)	3465 (58.6)	881 (61.4)	851 (56.7)	849 (57.4)	884 (59.1)
Allergic rhinitis, No. (%)	798 (13.5)	203 (14.1)	209 (13.9)	169 (11.4)	217 (14.5)
No. of chronic conditions in addition to asthma/allergic rhinitis, median (range)	0 (0-3)	0 (0-2)	0 (0-3)	0 (0-3)	0 (0-2)
No. of adults per child, mean (SD)	1.9 (0.5)	1.9 (0.5)	2.0 (0.5)	1.9 (0.5)	1.9 (0.5)
Age of adults, mean (SD), y	40.1 (6.0)	40.1 (6.2)	40.6 (6.0)	40.1 (5.8)	39.8 (5.8)
At least 1 adult with asthma, No. (%)	958 (16.2)	218 (15.2)	261 (17.4)	237 (16.0)	242 (16.2)
No. of additional children insured, mean (SD)	1.2 (1.0)	1.1 (1.0)	1.2 (1.0)	1.2 (1.0)	1.2 (1.0)
Nonmedication coinsurance rate, mean (SD)	25.6 (11.6)	21.0 (8.5)	25.1 (12.4)	29.0 (12.1)	27.3 (11.2)
Medication use					
Annual out-of-pocket cost for basket of asthma medications, mean (95% CI), \$	154 (152-156)	89 (88-90)	123 (121-124)	161 (159-162)	242 (238-245)
Days covered by an asthma prescription during 365-d follow-up, % (95% CI)	40.9 (40.2-41.5)	42.2 (40.9-43.6)	40.7 (39.4-41.9)	39.4 (38.1-40.6)	41.3 (40.0-42.6)
Health care use after initiating control therapy					
Asthma-related hospitalization during 365-d follow-up, No. (%)	121 (2.1)	20 (1.4)	28 (1.9)	33 (2.2)	40 (2.7)
Asthma-related emergency department visit during 365-d follow-up, No. (%)	220 (3.7)	62 (4.3)	52 (3.5)	48 (3.3)	58 (3.9)
Health care use prior to initiating control therapy					
Asthma-related hospitalization in 180 d prior to initiating control therapy, No. (%)	129 (2.2)	28 (2.0)	31 (2.1)	39 (2.7)	31 (2.1)
Asthma-related emergency department visit in 180 d prior to initiating control therapy, No. (%)	195 (3.3)	37 (2.6)	47 (3.1)	61 (4.1)	50 (3.3)

^aTable reports unadjusted analyses. Annual out-of-pocket cost and expenditures on hospitalization are in 2010 dollars. Mean nonmedication coinsurance rate is the mean out-of-pocket cost of all medical services (eg, hospitalizations, emergency department visits, durable equipment) divided by the total payment (out-of-pocket + health plan) for those services. The 25th, 50th, and 75th percentiles of annual out-of-pocket cost for asthma medications were \$100, \$140, and \$190, respectively.

Table 4. Factors Associated With Asthma Medication Use According to Age of Child^a

	Aged <5 Years		Aged 5-18 Years	
	Unadjusted Mean % of Days Covered by a Prescription Asthma Medication (95% CI)	Adjusted Relative % Change in Days Covered by a Prescription Asthma Medication (95% CI)	Unadjusted Mean % of Days Covered by a Prescription Asthma Medication (95% CI)	Adjusted Relative % Change in Days Covered by a Prescription Asthma Medication (95% CI)
Increase in annual out-of-pocket cost for basket of asthma medications by \$100		-1.3 (-4.5 to 2.0)		-3.6 (-6.5 to -0.6)
Child characteristics				
Increase in age of child by 1 y		-1.5 (-3.4 to 0.4)		-1.7 (-2.2 to -1.3)
Sex				
Male	47.2 (45.9 to 48.4)	5.4 (1.2 to 9.7)	41.3 (40.5 to 42.2)	1.9 (-1.0 to 4.9)
Female	44.5 (43.0 to 46.0)		40.2 (39.3 to 41.2)	
Allergic rhinitis				
Yes	49.7 (46.8 to 52.6)	11.1 (4.6 to 18.1)	46.3 (44.4 to 48.1)	14.3 (9.9 to 18.92)
No	45.6 (44.6 to 46.7)		40.0 (39.4 to 40.7)	
Increase in No. of chronic conditions in addition to asthma or allergic rhinitis by 1		7.7 (0.5 to 15.4)		3.8 (-1.9 to 9.9)
Increase in asthma-related hospitalizations in 180 d prior to starting control therapy by 1 visit		7.5 (-0.9 to 16.7)		9.5 (-1.4 to 21.6)
Increase in asthma-related emergency department visits in 180 d prior to starting control therapy by 1 visit		1.5 (-2.4 to 5.5)		2.4 (-1.3 to 6.3)
Family characteristics				
Adult with asthma				
Yes	46.8 (44.5 to 49.2)	3.8 (-1.9 to 10.0)	43.5 (41.8 to 45.1)	8.7 (4.5 to 13.1)
No	46.0 (45.0 to 47.1)		40.4 (39.7 to 41.1)	

^aUnadjusted mean percentages of days covered by a prescription asthma medication are shown for categorical variables. Adjusted relative percentage change in days covered by asthma medication was estimated from a multivariate, generalized linear model with annual out-of-pocket costs for a representative basket of asthma medications, nonmedication cost sharing, child and family characteristics, indicators for the year corresponding to control therapy initiation, and zip code demographic characteristics. Additional child, family, and zip code demographic characteristics adjusted for are described in the "Methods" section of the text.

(−3.6% relative change [95% CI, −6.5% to −0.6%] for each additional \$100 in annual out-of-pocket costs). In contrast, out-of-pocket asthma medication costs were not statistically significantly associated with use for children younger than 5 years. Asthma medication use declined with child age and was greater for children with allergic rhinitis in both age groups. Asthma-related hospitalizations and ED visits in the 180 days prior to initiating control therapy and zip code demographics were not statistically significantly associated with medication use in either age group ($P < .05$). Goodness of fit was assessed based on the Akaike information criterion (AIC) statistic (AIC, 0.47 for the model corresponding to children <5 years; AIC, 0.21 for the model corresponding to children aged 5-18 years).

TABLE 5 shows adjusted estimates of asthma medication and other health care service use associated with an increase in out-of-pocket asthma medication costs from the 25th to the 75th percentile of out-of-pocket costs (from \$100 to \$190 annually). The interquartile increase in out-of-pocket asthma medication costs was associated with a small but statistically significant reduction in the percentage of days covered by an asthma medication among children aged 5 to 18 years (41.7% [95% CI, 40.7%-42.7%] vs 40.3% [95% CI, 39.4%-41.3%]; $P = .02$) but no statistically significant change among younger children. Adjusted rates of asthma-related hospitalization were higher for children aged 5 to 18 years in the highest quartile of out-of-pocket asthma medication costs compared with the lowest quartile (2.4 [95% CI, 1.9-2.8] vs 1.7 [95% CI, 1.3-2.1] hospitalizations per 100 children; $P = .004$), but no statistically significant difference across quartiles was found for children younger than 5 years. There was no statistically significant difference in annual adjusted rates of ED use between patients between the 25th and 75th percentiles of out-of-pocket asthma medication costs for either age group.

Averaged across all children with asthma aged 5 to 18 years, total (patient + health plan) asthma-related

Table 5. Adjusted Asthma Medication and Other Health Care Use Associated With an Increase in Out-of-Pocket Asthma Medication Costs^a

	Annual Out-of-Pocket Cost for Asthma Medications, Mean (95% CI)		
	25th Percentile (\$100)	75th Percentile (\$190)	P Value
Aged <5 Years			
Percentage of days covered by a prescription asthma medication	46.5 (45.2-47.8)	45.9 (44.8-47.1)	.44
Total expenditure on asthma medications, \$	279 (194-364)	276 (192-360)	.50
Rate of asthma-related hospitalizations per 100 children	4.9 (4.1-5.8)	4.5 (3.5-5.3)	.43
Total expenditure on asthma-related hospitalizations among all children in sample, \$	246 (164-328)	224 (141-307)	.71
Total expenditure on asthma-related hospitalizations and medications among all children in sample, \$	525 (407-644)	500 (383-617)	.67
Rate of asthma-related emergency department visits per 100 children	7.4 (6.4-8.4)	8.4 (7.3-9.5)	.12
Rate of non-asthma-related hospitalizations per 100 children	5.5 (4.4-6.6)	5.2 (4.2-6.2)	.62
Aged 5-18 Years			
Percentage of days covered by a prescription asthma medication	41.7 (40.7-42.7)	40.3 (39.4-41.3)	.02
Total expenditure on asthma medications, \$	250 (176-324)	242 (170-314)	.007
Rate of asthma-related hospitalizations per 100 children	1.7 (1.3-2.1)	2.4 (1.9-2.8)	.004
Total expenditure on asthma-related hospitalizations among all children in sample, \$	130 (5-255)	145 (41-250)	.81
Total expenditure on asthma-related hospitalizations and medications among all children in sample, \$	380 (236-523)	387 (260-514)	.93
Rate of asthma-related emergency department visits per 100 children	3.8 (3.2-4.4)	3.7 (3.0-4.3)	.74
Rate of non-asthma-related hospitalizations per 100 children	3.2 (2.6-3.7)	2.7 (2.1-3.3)	.30

^aAnnual out-of-pocket costs and expenditures are in 2010 dollars. Total expenditures are sum of payments by patient and health plan.

hospital expenditures were not statistically significantly different between children in the highest and lowest quartiles of out-of-pocket asthma medication costs (\$145 [95% CI, \$41-\$250] per child in highest quartile vs \$130 [95% CI, \$5-\$255] in lowest; $P = .81$) (Table 5), while total asthma medication expenditures were statistically significantly lower in the highest quartile (\$242 [95% CI, \$170-\$314] vs \$250 [95% CI, \$176-\$324] per child; $P = .007$). Combining both effects, total expenditures per child on asthma-related medications plus hospitalizations were not statistically significantly different between the 25th and 75th percentiles of out-of-pocket asthma medication costs (\$380 [95% CI, \$236-\$523] vs \$387 [95% CI, \$260-\$514] per child; $P = .93$).

Sensitivity Analyses

In addition to adjusting for use of hospital services in the 180 days prior to starting asthma control therapy, we as-

sessed for confounding in the association of out-of-pocket asthma medication costs with asthma-related hospitalizations by estimating the association between out-of-pocket asthma medication costs and non-asthma-related hospitalizations. Out-of-pocket asthma medication costs were not statistically significantly associated with non-asthma-related hospitalizations (Table 5). In residual confounding analysis, we computed that the true odds ratio of hospitalization with respect to out-of-pocket asthma drug costs would become statistically indistinguishable from 1 if there were an unmeasured binary variable with an odds ratio of hospitalization of 2, an 80% prevalence in a highest-quartile out-of-pocket cost plan, and a 0% prevalence in a lowest-quartile out-of-pocket plan, a degree of selection thought to be unlikely.

We also explored whether our estimates were affected by the inclusion of

children who were not expected to use therapy daily year-round but only seasonally or on an as-needed basis. Limiting our follow-up period to 90 days and also examining seasonal use—both intended to capture short- rather than long-term use—revealed similar associations between out-of-pocket asthma medication costs and medication use and asthma-related hospitalizations (eTable 2). Restricting our sample to require a 12-month period without prior asthma control therapy—intended to reduce the probability of including children with prior intermittent use of control therapy—also did not affect the association of out-of-pocket medication costs with medication use and asthma-related hospitalizations (eTable 2). Finally, because out-of-pocket asthma medication costs varied at the plan-year level, we assessed whether our results were robust to a hierarchical model with nesting at the plan-year level. Our results were unchanged with this approach (eTable 3).

COMMENT

Despite evidence that greater medication cost sharing is associated with reduced medication use and increases in other health care utilization among adults, data are limited among children.^{9,10} We found that greater out-of-pocket asthma medication cost was associated with small but statistically significant reductions in medication use and total (patient + health plan) asthma medication expenditures among children aged 5 years or older with asthma. No association was found for children younger than 5 years. Among children aged 5 years or older, higher out-of-pocket asthma medication cost was also associated with more frequent asthma-related hospitalizations. However, there was no statistically significant association with ED visits or with total medication + asthma-related hospitalization expenditures.

Health care utilization by children relies on the purchasing decisions of parents, and children with chronic illnesses are susceptible to underuse of effective medical therapies.²³ Although most child

studies focus on the impact of insurance enrollment on those previously uninsured,^{12,24} our study explores whether impediments exist among insured children through greater medication cost sharing. Our study relates to prior research among children with attention-deficit/hyperactivity disorder after the introduction of multitier formularies,²⁵ studies investigating the association of sociodemographic and insurance characteristics with asthma medication use,^{19,26,27} as well as studies of Canadian children with asthma that document lower medication use²⁸ and increased hospitalizations and ED visits associated with greater drug cost sharing.²⁹ Our study adds to prior work by examining a large sample of children with asthma in the United States, where cost sharing may affect use differently than in Canada. We also analyzed the association of medication cost sharing with both medication and other health care utilization and explored how that association varied with child age. Our finding that greater out-of-pocket medication cost was not associated with lower asthma medication use among younger children suggests that parents may be less sensitive to medication costs for younger children, who traditionally have more severe disease.²⁰ In addition, parents may play a more active role in disease management for younger children with asthma compared with that for adolescents.

Our study had several limitations. Unobserved characteristics of children and families may explain the estimated association of out-of-pocket costs with medication use. However, selection bias is limited because the majority of employers in our study offered a single, employer-specific drug benefit regardless of the various medical plans they offered. For example, 97% of children had a choice of only a single drug plan from the employer providing coverage to their family. Although we did not have data on employer characteristics, we assessed for family selection into health plans by estimating the association between out-of-pocket asthma medication cost and non-asthma-related hospitalizations. If selection bias were important, one would expect greater

medication cost sharing to also be associated with greater non-asthma-related hospitalizations. We found no such association. In addition, our estimates were unaffected by adjustment for use of hospital services in the previous 180 days.

The intent of our study was to analyze the association of out-of-pocket asthma medication prices with medication use. While this would be straightforward if there were only a single medication to treat asthma and plans varied only in their co-payments for the medication, the reality is more complex. Several asthma medications exist, and plans vary in benefit designs, requiring the use of a “price index” to depict the prices faced by patients in different plans. Since our approach characterized plan prices by computing the out-of-pocket cost required to purchase a fixed, representative basket of asthma medications within a plan, it is possible that the reductions in medication use that we estimate in higher-cost plans were small because patients shift toward less-expensive medications within high-cost plans.

Mean use of asthma control therapy over a 365-day period was low in our study. A limitation of our sample is that it may have included children who were not expected to use therapy daily year-round; for example, if prescribed seasonally or on an as-needed basis. Limiting our follow-up period to 90 days and examining seasonal use—both intended to capture short- rather than long-term use—revealed a similar association between out-of-pocket medication cost and medication use. An additional limitation of our study was that the sample of children, though large, was not representative of all privately insured children. Because of a lack of family income data, our study was also unable to reliably assess the impact of income on medication and hospital utilization as has been done in prior studies.²⁹ Zip code-level income was not associated with medication use—not surprisingly given the coarseness of the measure. Our study also lacked clinical measures of asthma severity, which made exploration of overall asthma control impossible. Finally,

our measure of medication use, days supplied, may have overstated actual adherence to inhalational therapies,³⁰ though this measurement error should not vary systematically across health plans.

Our results contribute to ongoing discussions about generosity mandates for children. In addition to prohibiting health plans from limiting coverage of children with preexisting health conditions, the Affordable Care Act requires plans to cover preventive health services such as vaccines and well child visits at no cost to families.³¹ Our study suggests that medication generosity mandates have small effects on use and asthma-related hospitalizations, but other strategies to improve medication use, such as routine access to primary care and pulmonary specialists, written plans of care for families, and regularly scheduled follow-up appointments, may be important in improving medication use.²⁷ Low levels of medication use suggest that parents may not realize the benefits of prescription medications in childhood chronic illness.³² It is perhaps not surprising that children with asthmatic parents, who are presumably familiar with the importance of consistent medical therapy, had higher use of asthma medications than children of parents without asthma. Ultimately, despite its limitations, our study suggests that greater prescription medication cost sharing among children with asthma may lead to small reductions in use of important medications with unintended consequences of more frequent asthma-related hospitalizations.

Author Contributions: Dr Karaca-Mandic had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Karaca-Mandic, Jena, Joyce, Goldman.

Acquisition of data: Joyce, Goldman.

Analysis and interpretation of data: Karaca-Mandic, Jena, Joyce, Goldman.

Drafting of the manuscript: Karaca-Mandic, Jena, Joyce.

Critical revision of the manuscript for important intellectual content: Karaca-Mandic, Jena, Joyce, Goldman.

Statistical analysis: Karaca-Mandic, Jena, Goldman.

Obtained funding: Karaca-Mandic, Goldman.

Administrative, technical, or material support: Karaca-Mandic, Goldman.

Study supervision: Joyce, Goldman.

Conflict of Interest Disclosures: All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Dr Joyce reports consulting for Precision Health Economics and lectures/speakers bureau service for Pfizer. Dr Goldman reports consulting for Novartis and Bristol-Myers Squibb and serving on a panel of health advisors for the Congressional Budget Office. No other disclosures were reported.

Funding/Support: Support was provided by the National Institute of Child Health and Human Development (grant 1R03HD058203-01A1), the National Institute on Aging (grant 7R01AG02514), and the Roybal Center for Health Policy Simulation (grant 5P30AG024968).

Role of the Sponsor: The sponsors were not involved in the design and conduct of the study; collection, management, analysis, or interpretation of the data; or preparation, review, or approval of the manuscript.

Online-Only Material: eTables 1 through 3 and the Author Video Interview are available at <http://www.jama.com>.

Additional Contributions: We received thoughtful suggestions from Thomas Kinane, MD, and Emily Rubin, MD, JD, and assistance with data preparation from Patty St Clair. No compensation was received.

REFERENCES

1. Goldman DP, Joyce GF, Escarce JJ, et al. Pharmacy benefits and the use of drugs by the chronically ill. *JAMA*. 2004;291(19):2344-2350.
2. Joyce GF, Escarce JJ, Solomon MD, Goldman DP. Employer drug benefit plans and spending on prescription drugs. *JAMA*. 2002;288(14):1733-1739.
3. Johnson RE, Goodman MJ, Hornbrook MC, Eldredge MB. The effect of increased prescription drug cost-sharing on medical care utilization and expenses of elderly health maintenance organization members. *Med Care*. 1997;35(11):1119-1131.
4. Hsu J, Price M, Huang J, et al. Unintended consequences of caps on Medicare drug benefits. *N Engl J Med*. 2006;354(22):2349-2359.
5. Chandra A, Gruber J, McKnight R. Patient cost-sharing and hospitalization offsets in the elderly. *Am Econ Rev*. 2010;100(1):193-213.
6. Goldman DP, Joyce GF, Karaca-Mandic P. Varying pharmacy benefits with clinical status: the case of cholesterol-lowering therapy. *Am J Manag Care*. 2006;12(1):21-28.
7. Tamblyn R, Laprise R, Hanley JA, et al. Adverse events associated with prescription drug cost-sharing among poor and elderly persons. *JAMA*. 2001;285(4):421-429.
8. Tseng CW, Brook RH, Keeler E, Steers WN, Mangione CM. Cost-lowering strategies used by Medicare beneficiaries who exceed drug benefit caps and have a gap in drug coverage. *JAMA*. 2004;292(8):952-960.
9. Leibowitz A, Manning WG Jr, Keeler EB, Duan N, Lohr KN, Newhouse JP. Effect of cost-sharing on the use of medical services by children: interim results from a randomized controlled trial. *Pediatrics*. 1985;75(5):942-951.
10. Johnson TJ, Rimsza M, Johnson WG. The effects of cost-shifting in the State Children's Health Insurance Program. *Am J Public Health*. 2006;96(4):709-715.
11. US Census Bureau. *Current Population Survey: Annual Social and Economic Supplement*. Washington, DC: US Census Bureau; 2010.
12. Kogan MD, Newacheck PW, Blumberg SJ, et al. Underinsurance among children in the United States. *N Engl J Med*. 2010;363(9):841-851.
13. Bethell CD, Read D, Blumberg SJ, Newacheck PW. What is the prevalence of children with special health care needs? toward an understanding of variations in findings and methods across 3 national surveys. *Matern Child Health J*. 2008;12(1):1-14.
14. National Asthma Education and Prevention Program. Expert Panel Report 3 (EPR-3): guidelines

for the diagnosis and management of asthma—summary report 2007. *J Allergy Clin Immunol*. 2007;120(5)(suppl):S94-S138.

15. Adams RJ, Fuhlbrigge A, Guilbert T, Lozano P, Martinez F. Inadequate use of asthma medication in the United States: results of the Asthma in America national population survey. *J Allergy Clin Immunol*. 2002;110(1):58-64.

16. Goldman DP, Joyce GF, Lawless G, Crown WH, Willey V. Benefit design and specialty drug use. *Health Aff (Millwood)*. 2006;25(5):1319-1331.

17. Karaca-Mandic P, Joyce GF, Goldman DP, Laouri M. Cost sharing, family health care burden, and the use of specialty drugs for rheumatoid arthritis. *Health Serv Res*. 2010;45(5 pt 1):1227-1250.

18. Boushey HA, Sorkness CA, King TS, et al; National Heart, Lung, and Blood Institute's Asthma Clinical Research Network. Daily vs as-needed corticosteroids for mild persistent asthma. *N Engl J Med*. 2005;352(15):1519-1528.

19. Kozyrskiy AL, Mustard CA, Simons FE. Socioeconomic status, drug insurance benefits, and new prescriptions for inhaled corticosteroids in schoolchildren with asthma. *Arch Pediatr Adolesc Med*. 2001;155(11):1219-1224.

20. Akinbami L; Centers for Disease Control and Prevention National Center for Health Statistics. The state of childhood asthma, United States, 1980-2005. *Adv Data*. 2006;(381):1-24.

21. Duan N, Manning WG, Morris CN, Newhouse JP. A comparison of alternative models for the demand for medical care. *J Bus Econ Stat*. 1983;1(2):115-126.

22. Lin DY, Psaty BM, Kronmal RA. Assessing the sensitivity of regression results to unmeasured confounders in observational studies. *Biometrics*. 1998;54(3):948-963.

23. Halterman JS, Aligne CA, Auinger P, McBride JT, Szilagyi PG. Inadequate therapy for asthma among children in the United States. *Pediatrics*. 2000;105(1 pt 3):272-276.

24. Newacheck PW, Stoddard JJ, Hughes DC, Pearl M. Health insurance and access to primary care for children. *N Engl J Med*. 1998;338(8):513-519.

25. Huskamp HA, Deverka PA, Epstein AM, et al. Impact of 3-tier formularies on drug treatment of attention-deficit/hyperactivity disorder in children. *Arch Gen Psychiatry*. 2005;62(4):435-441.

26. Kozyrskiy AL, Mustard CA, Simons FE. Inhaled corticosteroids in childhood asthma: income differences in use. *Pediatr Pulmonol*. 2003;36(3):241-247.

27. Finkelstein JA, Lozano P, Farber HJ, Miroshnik I, Lieu TA. Underuse of controller medications among Medicaid-insured children with asthma. *Arch Pediatr Adolesc Med*. 2002;156(6):562-567.

28. Ungar WJ, Kozyrskiy A, Paterson M, Ahmad F. Effect of cost-sharing on use of asthma medication in children. *Arch Pediatr Adolesc Med*. 2008;162(2):104-110.

29. Ungar WJ, Paterson JM, Gomes T, et al. Relationship of asthma management, socioeconomic status, and medication insurance characteristics to exacerbation frequency in children with asthma. *Ann Allergy Asthma Immunol*. 2011;106(1):17-23.

30. Erickson SR, Coombs JH, Kirking DM, Azimi AR. Compliance from self-reported vs pharmacy claims data with metered-dose inhalers. *Ann Pharmacother*. 2001;35(9):997-1003.

31. Internal Revenue Service, Department of the Treasury; Employee Benefits Security Administration, Department of Labor; Office of Consumer Information and Insurance Oversight, Department of Health and Human Services. Interim final rules for group health plans and health insurance issuers relating to coverage of preventive services under the Patient Protection and Affordable Care Act. *Fed Regist*. 2010;75(137):41726-41760.

32. Henry RL, Cooper DM, Halliday JA. Parental asthma knowledge: its association with readmission of children to hospital. *J Paediatr Child Health*. 1995;31(2):95-98.