



Childhood Asthma Hospital Discharge Medication Fills and Risk of Subsequent Readmission

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Objective To assess the relationship between posthospitalization prescription fills for recommended asthma discharge medication classes and subsequent hospital readmission.

Study design This was a retrospective cohort analysis of Medicaid Analytic Extract files from 12 geographically diverse states from 2005-2007. We linked inpatient hospitalization, outpatient, and prescription claims records for children ages 2-18 years with an index hospitalization for asthma to identify those who filled a short-acting beta agonist, oral corticosteroid, or inhaled corticosteroid within 3 days of discharge. We used a multivariable extended Cox model to investigate the association of recommended medication fills and hospital readmission within 90 days.

Results Of 31 658 children hospitalized, 55% filled a beta agonist prescription, 57% an oral steroid, and 37% an inhaled steroid. Readmission occurred for 1.3% of patients by 14 days and 6.3% by 90 days. Adjusting for patient and billing provider factors, beta agonist (hazard ratio [HR] 0.67, 95% CI 0.51, 0.87) and inhaled steroid (HR 0.59, 95% CI 0.42, 0.85) fill were associated with a reduction in readmission at 14 days. Between 15 and 90 days, inhaled steroid fill was associated with decreased readmission (HR 0.87, 95% CI 0.77, 0.98). Patients who filled all 3 medications had the lowest readmission hazard within both intervals.

Conclusions Filling of beta agonists and inhaled steroids was associated with diminished hazard of early readmission. For inhaled steroids, this effect persisted up to 90 days. Efforts to improve discharge care for asthma should include enhancing recommended discharge medication fill rates. (*J Pediatr* 2015;166:1121-7).

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Asthma is a leading cause of childhood hospitalization and the most common cause of preventable hospitalization.^{1,2} Although the proportion of asthma hospitalizations resulting in an immediate readmission may be lower than other diagnoses,^{3,4} asthma represents a common cumulative cause of childhood readmission and an expensive, potentially avoidable outcome. For over 2 decades,⁵ the National Asthma Education and Prevention Program (NAEPP) has recommended a number of posthospitalization care medications, including continuation of inhaled short-acting beta-agonists and oral steroids, along with continuation or consideration of initiation of a preventive controller medication such as an inhaled corticosteroid.⁶ Single center or state studies of these individual medications reveal a broad range of prescribing or fill rates, ranging from 38%-71%,⁷⁻⁹ however, adherence with this set of recommended asthma discharge medications and the relationship with readmission have not been evaluated on a large scale. Given the current lack of useful quality indicators for inpatient care of asthma^{3,10} and a shifting focus toward accountable care, empirical evidence demonstrating the relationship of discharge medication fills and outcomes would be valuable to providers, payers, and policymakers.

In this study, we sought to determine the proportion of patients who filled recommended discharge prescriptions within 3 days of pediatric asthma hospital discharge and to assess the relationship between filling these prescriptions and hospital readmission. Given the timing of their physiologic effects, we hypothesized that filling of short-acting beta agonists and oral steroids within 3 days of hospital discharge would be associated with reduction in short-term readmission and that filling of inhaled steroids would influence readmission at later intervals.

Methods

We conducted a retrospective cohort study of Medicaid analytic extract (MAX) claims data for 12 states from 2005-2007. The protocol for the conduct of this

ED	Emergency department
HEDIS	Healthcare Effectiveness Data and Information Set
HR	Hazard ratio
MAX	Medicaid analytic extract
NAEPP	National Asthma Education and Prevention Program

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study was reviewed and determined not to be human subjects' research by the Children's Hospital of Philadelphia Institutional Review Board. MAX claims include distinct files for personal summary data, inpatient, outpatient drug, and other services' claims, the last of which includes outpatient and emergency department (ED) visits. For the purposes of this study, individual patient claims were linked across these 4 MAX claims files using a Medicaid unique identifier. The 12 states selected for this analysis included a geographically diverse sample with at least 2 states from each of the 4 census regions of the US. We included the most populous state from each census region (New York, Illinois, Texas, and California), and 8 states reported to have research quality MAX inpatient and drug encounter claims data.¹¹ Encounter claims represent provider-patient interactions or services under capitated payment delivery systems for which individual fee-for-service payments are not received.

Patients ages 2-18 years with claims for inpatient hospitalizations with primary diagnoses of asthma (*International Classification of Diseases, Ninth Revision Code 493.XX*) from January 1, 2006 to September 30, 2007 were included. This allowed for a 365-day look-back period to assess prior care and a 90-day observation period following discharge to assess for subsequent medication fills and hospitalizations. For those patients with multiple hospitalizations, we used only the first admission as the index admission. We excluded patients <2 years of age because other wheezing illnesses such as bronchiolitis may confound the diagnosis of asthma. In addition, we excluded patients who died during their index hospitalization or were discharged to care other than home or self-care.

The outcome of interest was time to inpatient readmission for a principal or secondary diagnosis of asthma within 90 days of index hospital discharge. We included secondary diagnoses of asthma to include readmissions for all asthma-related conditions. Our predictors of interest were pharmacy claims for: (1) short-acting beta agonists; (2) oral corticosteroids; and (3) inhaled corticosteroids or a combination inhaled steroid and long acting beta agonist between one day prior and 3 days subsequent to hospital discharge. We identified claims for asthma medication fills in the pharmacy dataset (which includes only outpatient medication dispensing) using the 9-digit National Drug Codes for medications within each category using the 2011 Healthcare Effectiveness Data and Information Set (HEDIS) lists.¹² Overall, there were 206 distinct codes for short-acting beta agonists, 1301 for oral steroids, and 143 for inhaled steroids.

Covariates included patient characteristics, including demographics, prior utilization and index hospitalization factors, and billing provider number. The billing provider represents the entity that submitted the inpatient claim, which could be either an individual physician or an institution. Demographic variables were age, sex, race/ethnicity, and enrollment in a Medicaid managed care plan at the time of index hospitalization. To account for forms of prior health care use that have been associated with subsequent hospitalization,^{13,14} we queried the inpatient, other services,

and pharmacy records in the 365 days preceding index admission for asthma-related hospitalizations, ED visits, oral steroid fills, and total non-oral steroid asthma medication fills. To account for severity of disease in the prior year, we assessed presence of persistent asthma by the HEDIS criteria¹⁵ and presence of complex chronic condition within the prior year, the latter of which has been associated with readmission.¹⁶ Covariates related to the index hospitalization included length of stay and the 5 most prevalent comorbid diagnoses during that stay. Lastly, to account for potential volume-outcome relationships, we calculated the volume of discharges per hospitalization billing provider and generated an ordinal variable for billing provider volume with 4 categories.

Statistical Analyses

We computed the proportion of immediate prescription fills for each of the 3 discharge medication categories, both overall and by individual covariate. To assess the general pattern of readmission over the 90-day interval following index discharge and the unadjusted relationships between medication fills and readmission, we constructed Kaplan-Meier failure curves depicting time to readmission with and without each medication. In further bivariate analysis, we assessed the relationship between individual independent variables and immediate medication fills for each medication, as well as 0- to 14- and 15- to 90-day readmission, using χ^2 tests for categorical variables and Student t tests for continuous variables.

We used a multivariable extended Cox model to investigate the association of recommended medication fills and hospital readmission. We assessed the proportional hazards assumption by visually inspecting the estimated log(-log) survival curves, which diverged around 14 days for all 3 medication exposure variables and then tested the statistical significance of time by medication interaction terms. The extended Cox model allowed for nonproportional hazards and provided relative measures of effect of the medication fills between 0-14 days and between 15-90 days. Extended Cox models used robust SEs at the billing provider level to account for the correlation between repeated measures within billing provider.

To estimate the cumulative risk of readmission for the treated relative to untreated groups for the primary exposure variables, we used a logistic regression model including the same covariates to derive estimated probabilities of readmission at 0-14 days and 15-90 days both with and without medication fills. The difference between the probability of readmission with fill and without fill is the absolute risk difference estimate and the relative risk difference is the quotient of the absolute risk difference and probability without fill.

Anticipating specific sources of bias and confounding, we performed a number of sensitivity analyses. To assess for interval censoring, we restricted our analysis to children who had at least 33 of 36 months of Medicaid enrollment and applied the same extended Cox model. Next, because some patients may have filled prescriptions for inhalers

immediately preceding hospitalization and had sufficient home supply of these medications at discharge, we repeated the extended Cox model counting beta agonist and inhaled steroid inhaler fills occurring in the 30 days prior to admission as posthospitalization fills. Anticipating potential differences in effect of the medications by asthma severity, we also performed an extended Cox model stratified by HEDIS persistent status. Lastly, we reran our extended Cox model restricting readmission events to only those with a primary asthma diagnosis.

Statistical analyses were conducted using SAS v 9.2 (SAS Institute, Cary, North Carolina) and Stata v 12.1 (Stata Corp, College Station, Texas). We used a standard 2-tailed *P* value of less than .05 to designate statistical significance.

Results

Between January 1, 2006, and September 3, 2007, 31 658 children were admitted to an inpatient unit for asthma. The cohort were 39% female, 37% non-Hispanic Black, 22% non-Hispanic white, and 32% Hispanic. The majority (61%) were covered by a managed care plan at the time of index hospital discharge; the remainder were covered by fee-for-service plan. The mean age of the cohort was 6.6 years (SD 4.3). The 5 most prevalent hospital-level comorbidities

were pneumonia (15%), hypoxemia (12%), upper respiratory infection (9%), contact dermatitis/eczema (5%), and dehydration (4%). One-half of the cohort (51%) met HEDIS criteria for persistent asthma, and 14% had a complex chronic condition in the year preceding admission.

Between the day preceding discharge and the 3 subsequent days, 17 363 children (55%) filled a prescription for a beta agonist, 18 135 (57%) for an oral steroid, and 11 708 (37%) for an inhaled steroid. Of the 16 163 who met criteria for HEDIS persistent asthma in the prior year, 6791 (42%) filled an inhaled steroid within 3 days. Similarly, the fill proportion was 46% for those who had at least 1 inhaled steroid fill in the prior year but none in the 30 days immediately preceding index admission. Factors most associated with medication fill included age, race/ethnicity, managed care coverage, length of stay, and prior utilization factors (Table 1). Accounting for inhaler fills in the 30 days preceding admission and 3 days following admission, a total of 21 074 children (67%) received a beta agonist fill and 14 281 (45%) received an inhaled steroid fill.

Within 90 days of discharge, 1986 children (6.3%) were readmitted for asthma, of whom 1471 (74.1%) had a primary diagnosis of asthma. Median time to admission was 40 days (IQR 18-62). Within 14 days of hospital discharge, 419 children (1.3%) were readmitted and an

Table 1. Index hospitalization patient characteristics and immediate medication fill by covariate

	N (% of cohort)	% Beta agonist (% of covariate)	<i>P</i> *	Oral steroid (% of covariate)	<i>P</i> *	Inhaled steroid (% of covariate)	<i>P</i> *
Overall (%)	31 658 (100)	17 363 (54.9)		18 135 (57.3)		11 708 (37.0)	
Female sex	12 355 (39.0)	6679 (54.1)	.02	6918 (56.0)	<.001	4537 (36.7)	.44
Age (y)							
2-4	13 091 (41.2)	7132 (54.5)		7577 (57.9)		4530 (34.6)	
5-11	13 729 (43.4)	7735 (56.3)	<.001	8008 (58.3)	<.001	5361 (39.1)	<.001
12-18	4838 (15.3)	2496 (51.6)		2550 (52.7)		1817 (37.6)	
Race/ethnicity							
Non-Hispanic white	6897 (21.8)	3553 (51.5)		3911 (56.7)		2369 (34.4)	
Non-Hispanic black	11 857 (37.5)	6818 (57.5)		7091 (59.8)		4675 (39.4)	
Hispanic	10 129 (32.0)	5514 (54.4)	<.001	5570 (55.0)	<.001	3708 (36.6)	<.001
Other	1040 (3.3)	549 (52.8)		569 (54.7)		346 (33.3)	
Unknown	1735 (5.5)	929 (53.5)		994 (57.3)		610 (35.2)	
Managed care coverage	19 236 (60.8)	11 595 (60.3)	<.001	12 023 (62.5)	<.001	7738 (40.2)	<.001
Length of stay							
<2 d	11 351 (35.9)	6363 (56.1)		7042 (62.0)		3837 (33.8)	
2-4 d	15 880 (50.2)	8672 (54.6)	<.001	9205 (58.0)	<.001	5980 (37.7)	<.001
≥5 d	4427 (14.0)	4427 (52.6)		1888 (42.7)		1891 (42.7)	
Comorbidities							
Pneumonia	4741 (15.0)	2633 (55.5)	.30	2572 (54.3)	<.001	1720 (36.3)	.28
Hypoxemia	3906 (12.3)	2099 (53.7)	.14	2185 (55.9)	.070	1468 (37.6)	.41
Upper respiratory infection	2688 (8.5)	1514 (56.3)	.11	1643 (61.1)	<.001	1035 (38.5)	.09
Contact dermatitis/eczema	1572 (5.0)	890 (56.6)	.15	979 (62.3)	<.001	675 (42.9)	<.001
Dehydration	1234 (3.9)	570 (46.2)	<.001	570 (46.2)	<.001	401 (32.5)	.001
Prior year utilization							
≥1 controller fill	15 501 (49.0)	8359 (53.9)	.001	9403 (60.7)	<.001	6542 (42.2)	<.001
Persistent asthma (HEDIS)	16 163 (51.1)	8777 (54.3)	.05	9829 (60.1)	<.001	6791 (42.0)	<.001
≥1 hospitalization†	2278 (7.2)	1161 (51.0)	<.001	1295 (56.9)	.210	942 (41.4)	<.001
≥1 ED visit	8715 (27.5)	4770 (54.7)	.81	5345 (61.3)	<.001	3679 (42.2)	<.001
≥1 oral steroid fill	15 493 (48.9)	8587 (55.4)	.04	9628 (62.1)	<.001	6416 (41.4)	<.001
≥1 outpatient visit	20 700 (65.4)	11 642 (56.2)	<.001	12 490 (60.3)	<.001	8018 (38.7)	<.001
CCC	4303 (13.6)	2211 (51.4)	<.001	2360 (54.9)	.001	1536 (35.7)	.06

CCC, complex chronic condition.

**P* values represent the result of significance tests of the proportion filling prescriptions with respect to the indicated covariate. For binary variables (eg, pneumonia), we present the proportion of the covariate with the indicated value who filled, but not the comparison group (eg, no pneumonia).

†Reflects number of patients admitted in 2006 with a prior hospitalization as the 2007 cohort had no prior hospitalization by definition.

additional 1567 children (5.0%) were readmitted between 15 and 90 days. Compared with those not readmitted, patients who were readmitted had significantly higher average numbers of prior hospitalizations, ED visits, oral steroid courses, and non-ED outpatient visits in the year preceding index admission at both readmission intervals (**Table II**).

Discharge Medication Fills and Readmission

In multivariable analysis, children with a beta agonist (hazard ratio [HR] 0.67, 95% CI 0.51, 0.87) or inhaled steroid fill (HR 0.59, 95% CI 0.42, 0.85) had a lower hazard of readmission within 14 days compared with those who did not; oral corticosteroid fill was also associated with a reduced readmission hazard at 14 days but was not statistically significant (HR 0.79, 95% CI 0.60, 1.04; **Figure**). Over the 15- to 90-day interval, only inhaled steroid fill was associated with a reduction in readmission hazard (HR 0.87, 95% CI 0.77, 0.98).

The **Figure** depicts the readmission HRs for those with the various permutations of multiple medication fills compared with the reference group with no fills. Patients who filled all 3 recommended medications following discharge had the lowest hazard of readmission within 14 days (HR 0.31, 95% CI 0.16, 0.60) and represented the only multiple fills category with a statistically significant reduction in readmission hazard between 15 and 90 days (HR 0.83, 95% CI 0.72, 0.97).

In terms of absolute risk and relative risk differences, the adjusted probability of readmission at 14 days decreased from 1.58% to 1.03% (35% relative reduction) with beta agonist fill, from 1.52% to 0.90% (41%) with inhaled steroid fill, and from 5.27% to 4.61% (13%) with inhaled steroids between 15 and 90 days.

Sensitivity Analyses

Restricting to a cohort with at least 33 months of Medicaid enrollment did not alter the direction or significance of any of the individual medication effects at either interval (**Table III**). Accounting for receipt of a beta agonist and inhaled steroid fills in the 30 days preceding admission, the effects and significance of beta agonists did not change at either interval, whereas inhaled steroid fill was no longer associated with a statistically significantly lower readmission hazard within 14 days (HR 0.73, 95% CI 0.51, 1.04). Stratifying by HEDIS persistent criteria in the preceding year, the relationship between inhaled steroid fill and reduced readmission hazard retained statistical significance for children who met HEDIS persistent criteria at 14 days. The marginal loss of statistical significance for inhaled steroids at other intervals appears to be driven by a loss of precision, as the HRs remained similar between HEDIS strata. The effect of other medications did not differ demonstrably between strata,

Table II. Readmission status by patient factors at 0-14 days and 15-90 days

	0-14 d		P	15-90 d		P
	Readmitted	Not readmitted		Readmitted	Not readmitted	
Overall (%) [*]	419 (1.3)	31 239 (98.7)		1567 (5.0)	30 091 (95.0)	
Female sex	166 (39.0)	12 189 (39.6)	.80	651 (41.5)	11 704 (38.9)	.04
Age (y)						
2-4	170 (40.6)	12 921 (41.4)		681 (43.5)	12 410 (41.2)	
5-11	164 (39.1)	13 565 (43.4)	.012	613 (39.1)	13 116 (43.6)	.001
12-18	85 (20.3)	4753 (15.2)		273 (17.4)	4565 (15.2)	
Race/ethnicity						
Non-Hispanic white	96 (22.9)	6801 (21.8)		335 (21.4)	6562 (21.8)	
Non-Hispanic black	172 (41.1)	11 685 (37.4)		627 (40.1)	11 230 (37.3)	
Hispanic	109 (26.0)	10 020 (32.1)	.006	457 (29.2)	9672 (32.1)	.005
Other	8 (1.9)	1032 (3.3)		41 (2.6)	999 (3.3)	
Unknown	34 (8.1)	1701 (5.4)		107 (6.8)	1628 (5.4)	
Managed care coverage	276 (65.9)	18 960 (60.7)	.03	938 (59.9)	18 298 (60.8)	.45
Length of stay						
<2 d	129 (30.8)	11 222 (35.9)		520 (33.2)	10 831 (36.0)	
2-4 d	223 (53.2)	15 657 (50.1)	.08	748 (47.7)	15 132 (50.3)	<.001
≥5 d	67 (16.0)	4360 (14.0)		299 (19.1)	4128 (13.7)	
Comorbidities						
Pneumonia	101 (24.1)	4640 (14.9)	<.001	379 (24.2)	4362 (14.5)	<.001
Hypoxemia	44 (10.5)	3862 (12.4)	.25	291 (18.6)	3615 (12.0)	<.001
Upper respiratory infection	31 (7.4)	2657 (8.5)	.42	206 (13.2)	2482 (8.3)	<.001
Contact dermatitis/eczema	29 (6.9)	1543 (4.9)	.06	147 (9.4)	1425 (4.7)	<.001
Dehydration	21 (5.0)	1213 (3.9)	.24	91 (5.8)	1143 (3.8)	<.001
Prior year utilization						
≥1 controller fill	260 (62.1)	15 241 (48.8)	<.001	1013 (64.7)	14 488 (48.2)	<.001
Persistent asthma (HEDIS)	262 (62.5)	15 901 (50.9)	<.001	1093 (69.8)	15 070 (50.1)	<.001
Prior hospitalizations, mean (SD) [†]	0.32 (0.79)	0.15 (0.50)	<.001	0.45 (1.04)	0.13 (0.45)	<.001
Prior ED visits, mean (SD)	0.72 (1.34)	0.46 (1.01)	<.001	0.92 (1.72)	0.44 (0.96)	<.001
Oral steroid fills, mean (SD)	1.65 (2.19)	1.08 (1.65)	<.001	2.03 (2.46)	1.04 (1.59)	<.001
Outpatient visits, mean (SD)	5.15 (7.48)	3.56 (5.28)	<.001	4.94 (6.80)	3.51 (5.22)	<.001
CCC	138 (32.9)	4165 (13.3)	<.001	349 (22.3)	3954 (13.1)	<.001

^{*}Percentages in "overall" row are of row percentages, whereas others are column percentages.

[†]Reflects number of patients admitted in 2006 with a prior hospitalization as the 2007 cohort had no prior hospitalization by definition.

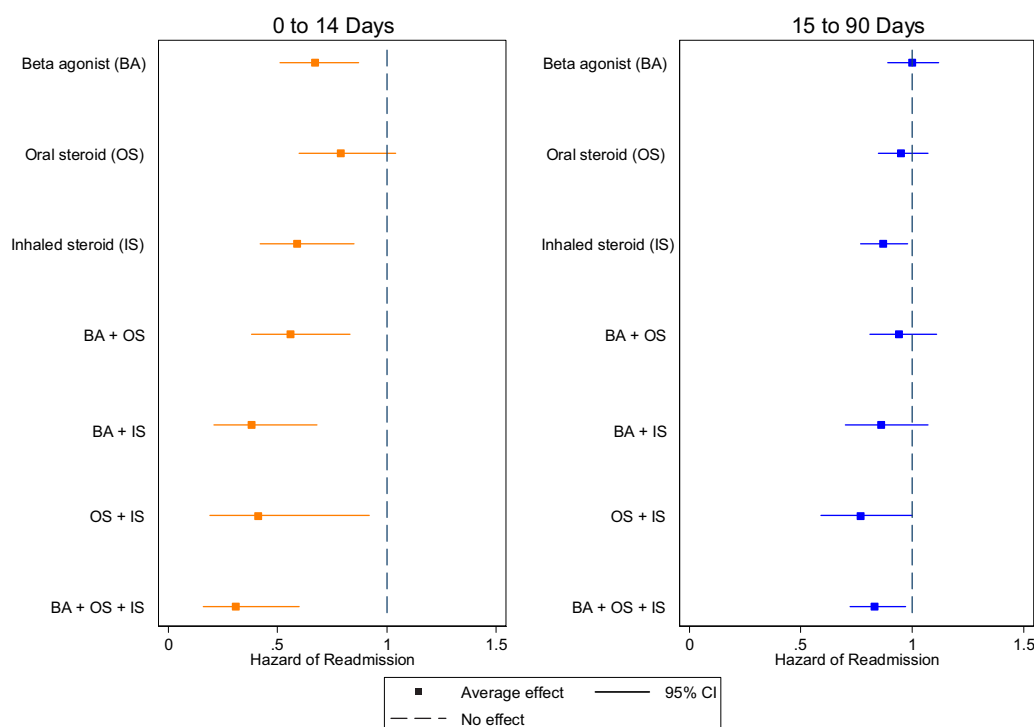


Figure. Discharge medication fills and readmission hazard at 14 days and 15-90 days.

with the exception of beta agonist fill demonstrating greater effect in those who did not meet HEDIS persistent asthma criteria.

Restricting to only readmissions for a primary diagnosis of asthma, our results were similar, with the following minor exceptions: oral steroid fill was associated with a statistically significant reduction in 14-day readmissions (HR 0.69, 95% CI 0.51, 0.95), whereas inhaled corticosteroid fill was only marginally associated with readmission hazard reduction (HR 0.89, 95% CI 0.78, 1.01).

Lastly, because some hospitals may have routinely provided discharge medications to inpatients from their inpatient pharmacy, we assessed the number of hospitals whose patients had postdischarge fill rates of <10% (which would reflect a pre-discharge provision of medications practice). Of the 339 billing providers with >20 discharges, only 3 (1%) had fill rates of <10% for beta agonists, 7 (2%) for oral steroids, and 17 (5%) for inhaled steroids, suggesting that this practice was infrequent.

Discussion

In this study of Medicaid claims, approximately 55% of children hospitalized for asthma filled a prescription for a beta agonist or oral steroid within 3 days of discharge and 37% filled an inhaled steroid prescription. Those who filled prescriptions for short-acting beta agonists and inhaled steroids experienced early readmission less frequently than children who did not, and those who filled inhaled corticosteroids

experienced 15- to 90-day readmission less frequently than those who did not.

A number of these findings are consistent with prior studies regarding individual medication classes. A study of Tennessee Medicaid claims demonstrated that a similar percentage (56%) of hospitalized children filled an oral steroid prescription within 7 days of discharge.⁷ The analogous proportions of beta agonist and inhaled steroid fills are less well described. Previously reported rates of inhaled steroid prescribing at hospital discharge range from 38%-71%, depending on how narrowly asthma is defined.^{8,9} The 45% inhaled steroid fill rate in the 30 days preceding hospitalization to 3 days after discharge that we found is consistent with these findings. With respect to prior research on medication effects, a study of children and adults in Canada assessed the impact of inhaled corticosteroids on asthma readmission and demonstrated a similar protective effect on readmission in the 3 months following discharge.¹⁷ No such study has been conducted on a large scale in the US.

This study adds to the existing literature by demonstrating the effects of recommended medication classes on short-term readmission. Our main model and each sensitivity analysis demonstrate an association of beta agonist fill (and borderline association of oral steroid fill) with lower early readmission hazard that is both biologically plausible and consistent with current expert panel recommendations.⁶ Continued access to rescue bronchodilation and systemic steroids at home may mitigate further symptoms and inflammatory response if patients return to an

Table III. Main effects of recommended medications on readmission from main model and sensitivity analyses

Model	N	HR for readmission (95% CI)					
		Short-acting beta agonists		Oral steroid		Inhaled steroid	
		14 d	15-90 d	14 d	15-90 d	14 d	15-90 d
Main model	31 658	0.67 (0.51, 0.87) <i>P</i> = .003	1.01 (0.89, 1.12) <i>P</i> = .97	0.79 (0.60, 1.04) <i>P</i> = .09	0.95 (0.85, 1.07) <i>P</i> = .42	0.59 (0.42, 0.85) <i>P</i> = .004	0.87 (0.77, 0.98) <i>P</i> = .02
Near-full enrollment	20 222	0.69 (0.50, 0.95) <i>P</i> = .02	1.05 (0.91, 1.22) <i>P</i> = .47	0.82 (0.60, 1.13) <i>P</i> = .23	0.93 (0.81, 1.07) <i>P</i> = .31	0.56 (0.38, 0.83) <i>P</i> = .004	0.86 (0.74, 0.99) <i>P</i> = .05
Recent inhaler fills	31 658	0.68 (0.55, 0.84) <i>P</i> ≤ .001	1.11 (0.96, 1.27) <i>P</i> = .16	0.72 (0.54, 0.97) <i>P</i> = .03	0.92 (0.82, 1.03) <i>P</i> = .15	0.73 (0.51, 1.04) <i>P</i> = .08	0.85 (0.75, 0.96) <i>P</i> = .007
HEDIS persistent	16 163	0.76 (0.57, 1.03) <i>P</i> = .08	0.94 (0.83, 1.07) <i>P</i> = .37	0.76 (0.52, 1.10) <i>P</i> = .15	0.95 (0.84, 1.08) <i>P</i> = .44	0.61 (0.43, 0.87) <i>P</i> = .006	0.88 (0.76, 1.01) <i>P</i> = .07
Non-HEDIS persistent	15 495	0.53 (0.36, 0.79) <i>P</i> = .002	1.09 (0.87, 1.38) <i>P</i> = .45	0.88 (0.63, 1.23) <i>P</i> = .45	0.94 (0.74, 1.18) <i>P</i> = .57	0.56 (0.31, 1.01) <i>P</i> = .06	0.84 (0.67, 1.06) <i>P</i> = .14

environment with continued exposure to asthma triggers or prior to flare resolution. With respect to inhaled steroids, prior studies suggest that the anti-inflammatory effects of inhaled steroids on pulmonary function may not be experienced for 7-14 days after initiation.¹⁸⁻²⁰ At least 1 prior study demonstrated sustained pulmonary function improvement with inhaled steroids following treatment with systemic steroids compared with placebo.²¹ Given that inhaled steroid fills immediately follow asthma hospitalization in the current study and that nearly 100% of children receive systemic steroids during asthma hospitalization,³ our finding of a protective effect on immediate readmission may reflect sustained pulmonary function improvement.

Given their consistency with existing data and the biologic plausibility of the medication effects, our findings have implications for the care of children who are discharged from the hospital with asthma. Continuation of beta agonists and oral steroids, although universally recommended by the NAEPP, appears inconsistent, despite effects on reducing readmission within the first 2 weeks of discharge. Although the recommendation of the NAEPP regarding the initiation of an inhaled steroid at the time of discharge is not universal, we found that even among patients where this care is recommended (ie, patients with at least 1 inhaled steroid fill in the prior year but none in the month preceding admission), the proportion with an immediate fill was only 46%. This proportion may reflect either a low prescription rate or low rate of prescription filling. In either case, the effect of inhaled steroids on reducing overall hospitalization is well established²²⁻²⁴ and in light of their effect on readmission at both intervals, discharging providers and those that reimburse hospital care should consider strategies to enhance the receipt of inhaled steroids at discharge. One potential method to enhance receipt of these medications is to dispense them with the families at the time of discharge, either from an inpatient or outpatient pharmacy.

Our analyses are subject to a number of limitations. First, this is a study of medication filling and not medication prescribing or administration. As alluded to above, prescribing of these recommended medications at discharge is not

universal; however, children prescribed discharge medications are likely to have more severe disease than those who were not, which should bias our results to the null. Even though we presume that filling a prescription makes a patient more likely to take it, this has not been empirically demonstrated. In addition, given our inability to ascertain inpatient medication dispensing, we were unable to assess if discharge medications were provided by inpatient pharmacies at the time of discharge, but our sensitivity analysis suggests that this was an infrequent practice.

A source of confounding that might bias our results toward an effect is an “enabled parent effect”: families that fill their medications may be more likely to engage in other activities that are known to improve asthma control, such as reducing dust, smoke, or cockroach exposure in their homes.^{25,26} Yet, if medication fill was simply a marker of an enabled parent, we would expect to see a continued effect of short-acting medications beyond the 15 days, which we did not observe.

Although the absolute risk reduction we identified is small, our results represent the average medication effects across diverse populations. Because asthma readmissions rates vary by hospital,²⁷ and specific populations vary with respect to steroid or beta agonist responsiveness,^{28,29} greater effects may be demonstrated in specific subpopulations. Further, hospital readmission represents a relatively extreme adverse event for asthma and few discharge practices have demonstrated effects on asthma readmission in pediatrics.³⁰ Less dramatic but more prevalent adverse outcomes, such as ED visits, school day absences, missed parental work, and diminished quality of life, are worthy of future study.

Lastly, the data used in this analysis was from 2005-2007. Because relatively little has changed with respect to asthma discharge care recommendations and we were primarily interested in the association between medication fill and readmission, it is unlikely that more recent data would provide different results in terms of magnitude and significance of these associations, though current rates of medication fills and readmissions may be different.

These findings suggest that children hospitalized for asthma should be prescribed and fill recommended discharge care medications. Even though the absolute risk reduction

associated with medication fills is modest, these data may inform interventions to improve discharge transitional care. ■

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