Rehospitalization for Childhood Asthma: Timing, Variation, and Opportunities for Intervention

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Objective To assess the timing of pediatric asthma rehospitalization, variation in rate of rehospitalization across hospitals, and factors associated with rehospitalization at different intervals.

Study design Retrospective cohort analysis of 44 204 hospitalizations for children with asthma within 42 children's hospitals between July 2008 and June 2011. The main outcome measures were rehospitalization for asthma within 7, 15, 30, 60, 180, and 365 days of an index asthma admission.

Results The rate of asthma rehospitalization ranged from 0.5% (n = 208) at 7 days to 17.2% (n = 7603) at 365 days. Black patients and patients with public insurance had higher odds of rehospitalization at 60 days and beyond ($P \leq .01$ for both). Adolescents (12- to 18-year-old), patients with a diagnosis of a complex chronic condition, and patients with a prior year asthma admission had higher odds of rehospitalization at every time interval ($P \leq .001$ for all). Significant hospital variation in case-mix adjusted rates of rehospitalization existed at each time interval ($P \leq .01$ for all). Rates at 365 days were ≤10.9% for the top 10% of hospitals; if all hospitals achieved this rate, 36.6% of rehospitalizations might have been avoided.

Conclusions Significant variation in asthma rehospitalization rates exists across children's hospitals from 7 to 365 days after an index admission. Racial/ethnic and economic disparities emerge at 60 days. By 1 year, rehospitalizations account for 1 in 6 hospitalizations. Assessing asthma rehospitalizations at longer intervals may augment our current understanding of and approach to post-hospitalization care improvement. *(J Pediatr 2014;164:300-5)*.

Although only a small percentage of the nearly 7 million US children with asthma are admitted to the hospital in a given year, hospitalization accounts for nearly one-third of national pediatric asthma costs.[1,2] Prior studies demonstrate that upwards of 40% of pediatric asthma hospitalizations are repeat hospitalizations (ie, the child has been hospitalized for asthma previously),[3-5] suggesting that reduction of repeat hospitalization may be an important priority area for care improvement. Furthermore, some repeat hospitalizations are avoidable; a number of hospital-centered interventions have reduced repeat hospitalization well beyond the month after discharge.[6-9]

However, in clinical practice, it is difficult to determine which hospitalized children with asthma are at risk for experiencing a subsequent asthma rehospitalization. Delineating risk factors for short- and long-term asthma rehospitalization may help to target discharge transition and chronic care improvement efforts to high-risk populations. Therefore, we performed a retrospective cohort analysis of asthma hospitalizations at 42 US children's hospitals to describe the prevalence and timing of repeat hospitalization for pediatric asthma and the factors associated with rehospitalization at different time intervals. We also assessed variation in asthma rehospitalization rates across hospitals and local areas to describe what rates might be achievable with high quality of care.

Methods

This is a longitudinal, retrospective cohort study of the Pediatric Health Information System (PHIS), an administrative database with inpatient data from 42 free-standing children's hospitals affiliated with the Children's Hospital Association. Included hospitals are distributed throughout the 4 US census regions (Northeast [16.7%], South [33.3%], Midwest [26.2%], and West [23.8%]). All are located in urban metropolitan statistical areas. The median bed-size of the hospitals was 290 (IQR 247, 343). All but one was categorized as a teaching hospital. PHIS has a unique identifier for each patient that permits longi-

APR-DRG	All-Patient Refined Diagnosis-Related Group
CCC	Complex chronic condition
ICU	Intensive care unit
PHIS	Pediatric Health Information System

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tudinal tracking of individual patients rehospitalized to the same PHIS hospital. The Boston Children's Hospital Institutional Review Board approved the study.

We analyzed hospital discharges of patients ≥2-years-old admitted for asthma (All-Patient Refined Diagnosis-Related Group [APR-DRG] of asthma [v20 141]) from 7/1/08-6/30/10, following each child for 365 days from the date of discharge within this interval. Children <2-years-old were excluded because other wheezing disorders (eg, bronchiolitis) often confound the diagnosis of asthma. We excluded index hospitalizations during which patients died.

Outcome measures were repeat admission to the same hospital for asthma (APR-DRG v20 141) within 7, 15, 30, 60, 180, and 365 days of an index admission for asthma. If a patient was hospitalized again following a rehospitalization within 365 days of the index admission, the initial rehospitalization was counted as an index admission for the second rehospitalization, and so forth.

Demographic characteristics included age at index admission (using National Heart, Lung, and Blood Institute age ranges of 2-4, 5-11, 12-18, and >18 years), race/ethnicity (non-Hispanic Black, non-Hispanic White, Hispanic, Other), sex, and primary insurance at index admission (public, private, self-pay/no-charge, other type of insurance).

We used an existing grouping of pediatric complex chronic conditions (CCC) to assess whether comorbid conditions influence the risk of asthma rehospitalization. CCC indicate the presence of a chronic illness that is expected to last ≥12 months and involve multiple organ systems or involve 1 organ system but require specialty pediatric care and hospitalization. CCC include pediatric cardiovascular, congenital/genetic defect, gastrointestinal, hematologic, malignancy, metabolic, neuromuscular, renal, and respiratory diagnoses[10]; these diagnoses are associated with higher risk of repeat admission.[11] Presence of a CCC was identified with *International Classification of Diseases-9-Clinical Modification* codes. Up to 21 diagnosis codes are provided per hospitalization.

Index hospitalization characteristics included use of magnesium for enhanced bronchodilation, APR-DRG severity of illness (mild [1]; moderate [2]; severe [3]; and extremely severe [4]), use of intensive care unit (ICU) services during the admission, length of hospital stay, and discharge disposition (to home with or without nursing, or post-discharge care facility). We also included asthma admission in the year prior to the index admission, which has been strongly associated with asthma rehospitalization in prior studies.[4,12]

Statistical Analyses

Demographic, clinical, and hospitalization characteristics were compared for index hospitalizations where another hospitalization did and did not occur within 365 days using χ^2 tests. Covariates with a P value <.20 in bivariate analysis were retained in a multivariate logistic regression model with generalized linear mixed effects using the hospital variable as a random effect at each readmission time interval. Although we labeled this random effect "hospital," we acknowledge that it likely includes effects that may be attributable to outpatient and community-level factors that influence rehospitalization rates. In multivariate analysis, variables retained in the final model were included at each time interval to allow comparison of the models across time intervals. P values <.05 were considered statistically significant.

To estimate potentially avoidable rehospitalizations at each interval, we rank-ordered each hospital by its rehospitalization rate, adjusted for age and CCC, and determined the rate corresponding with the top decile of hospitals (the 10% with the lowest rates). Performance at the 10th percentile has been used to establish performance benchmarks.[13] We determined the number of rehospitalizations that would be avoided if each hospital's adjusted rate was equivalent to the 10th performance percentile. We then calculated a potential inpatient cost savings estimate for these 42 hospitals by multiplying this estimated proportion of avoidable rehospitalizations by the overall cost of rehospitalization for all hospitals in that interval. To assess the stability of observed hospital rehospitalization rankings, we performed a Spearman correlation of hospital rankings in the first year (2009) to the second year (2010) for 2 rehospitalization intervals (30 and 365 days).

Costs were estimated using the adjusted total ratio of costs to charges variable reported in PHIS, which reflects the total charges reported by the hospital adjusted by the Centers for Medicare and Medicaid Services wage/price index for the hospital's location. Data were analyzed using SAS software, v. 9.2 (SAS Institute, Cary, North Carolina).

Results

From July 1, 2008-June 30, 2010, 36 601 patients had 44 204 hospitalizations in 42 children's hospitals. Characteristics of the cohort appear in **Table I**. Asthma rehospitalization rates ranged from 0.5% (n = 208) at 7 days to 17.2% (n = 7603) at 365 days (**Figure**), and aggregate costs of asthma rehospitalizations ranged from $3.3 million at 7 days to $30.8 million at 365 days. Of patients rehospitalized within 365 days, 75.0% had 1 repeat admission, 15.9% had 2, 5.0% had 3, and 4.1% had ≥4.

Bivariate Analysis

At 365 days, rehospitalization varied significantly by race/ethnicity ($P \leq .001$), with lower rates for Whites (11.9%) than for Blacks (22.2%) or Hispanics (14.5%). Rehospitalization rates also varied by age ($P \leq .001$), with higher rates observed in 12- to 18-year-olds (22.8%) than 5- to 11-year-olds (16.5%) and 2- to 4-year-olds (15.9%). There was also significant variation in repeat hospitalization by insurance status ($P \leq .001$), with higher rates, for example, for children with public insurance (19.6%) vs private insurance (13.4%). Patients with a CCC had higher rehospitalization rates than patients without a CCC (25.7% vs 16.5%, $P \leq .001$).

Rates also varied by length of stay ($P \leq .001$), ranging from 13.8% for those admitted for 1 day to 23.3% for those admitted for ≥5 days. Rehospitalization rates were higher in patients who experienced a prior asthma admission during

Table I. Demographic, index hospitalization characteristics, and 365-day asthma rehospitalization

	% of Overall cohort (n = 44 203)	% Rehospitalized in 365 d (n = 7603)	*P* value
Total asthma discharges	-	17.2	
Race/ethnicity			
Black (non-Hispanic)	46.6	22.2	
White (non-Hispanic)	27.3	11.8	
Hispanic	16.8	14.5	<.001
Other	7.9	13.0	
Missing	1.4	11.7	
Sex			
Male	61.1	16.7	<.001
Female	38.9	18.0	
Age (y)			
2-4	38.5	15.9	
5-11	46.5	16.5	<.001
12-18	14.5	22.8	
>18	0.5	22.3	
Principal payer			
Public	57.7	19.6	
Private	30.2	13.4	
Self-pay/no-charge	3.0	12.7	<.001
Other	5.2	14.5	
Missing	3.9	17.9	
Length of stay (d)			
1	40.1	13.8	<.001
2	33.5	18.2	
3-4	20.0	20.4	
>4	6.4	23.3	
Disposition			
Home	98.3	17.1	<.001
Other	1.7	22.7	
Prior year admission			
No	83.6	12.9	<.001
Yes	16.4	39.0	
Magnesium administered			
No	81.5	16.3	<.001
Yes	18.5	19.5	
Severity level			
1 and 2	94.7	17.1	.03
3 and 4	5.3	18.8	
ICU flag			
No	87.3	17.0	.002
Yes	12.7	18.6	
CCC			
No	92.3	16.5	<.001
Yes	7.7	25.7	

the 365 days before their index admission compared with those without a prior admission (39.0% vs 12.9%, $P \leq .001$). Rates were higher in patients who used ICU services (18.6% vs 17.0%, $P = .002$) and in patients with APR-DRG severity score of 3 or 4 compared with 1 or 2 (18.8% vs 17.1%, $P = .03$; **Table I**).

Multivariate Analysis

After controlling for other covariates, prior year asthma admission, age 12-18 years, and presence of a CCC were significantly associated with higher risk of rehospitalization at each time interval ($P \leq .001$ for all; **Table II**). Black race/ethnicity and public insurer were associated with higher risk of rehospitalization at 60 days and beyond ($P \leq .01$ for all).

There was significant hospital-level variation in adjusted rehospitalization rates at each time interval ($P \leq .01$ for all). Over time, children in hospitals with adjusted rates who were 1 SD above the mean had an odds of repeat hospitalization that ranged from 1.3 (95% CI 1.2, 1.8) to 1.4 (95% CI 1.3, 2.1) compared with children in hospitals with adjusted rates at the mean (**Table II**).

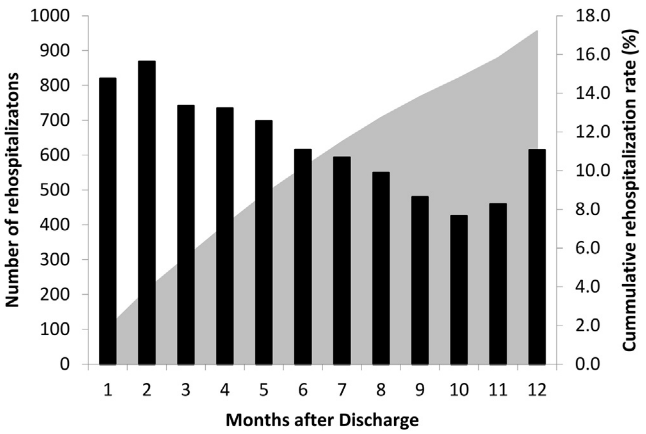

Figure. Pediatric asthma rehospitalization prevalence and rates.

Potentially Avoidable Rehospitalizations

At 7 days, the hospitals performing within the top 10th percentile had rehospitalization rates of ≤0.2% and the remaining hospitals had a median rehospitalization rate of 1.6% (IQR 1.3, 2.3; **Table III**). If the remaining hospitals had rates equal to the 10th percentile, 59.1% of the rehospitalizations and their associated inpatient costs may have been avoided at 7 days. By 365 days, the hospitals performing within the top 10th percentile had rehospitalization rates of ≤10.9% and the remaining hospitals had a median rehospitalization rate of 17.1% (IQR 15.1, 18.8). If the remaining hospitals had rates of 10.9%, 36.6% of rehospitalizations and their associated costs might have been avoided at 365 days (**Table III**). The four hospitals in the top 10th percentile did not differ from the other hospitals by region, size, or teaching status.

Hospital rankings between the first and second year of the cohort were less correlated for 30-day rehospitalization rates (Spearman coefficient = 0.27 [$P = .08$]) than for 365-day rehospitalization rates (Spearman coefficient = 0.76 [$P < .001$]).

Discussion

In a study of 42 children's hospitals, we found that asthma rehospitalization rates are relatively low in the immediate post-discharge interval, but about 1 in every 6 patients discharged with a primary diagnosis of asthma will be rehospitalized within a year for asthma. Some patient characteristics are associated with higher risk of repeat hospitalization at each time interval, whereas other characteristics are associated with risk at more distant time intervals. Significant

Table II. Multivariate analysis of risk factors for asthma rehospitalization

	7 d	15 d	30 d	60 d	180 d	365 d
Covariate	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Female sex	0.7 (0.6, 1.0)	0.9 (0.7, 1.1)	1.0 (0.8, 1.1)	1.0 (0.9, 1.1)	1.1 (1.0, 1.1)*	1.1 (1.0, 1.1)*
Age group	‡	‡	‡	‡	‡	‡
Over 18 y	10.0 (4.3, 23.3)	3.9 (1.8, 8.4)	2.3 (1.3, 4.3)	1.5 (0.9, 2.5)	1.1 (0.8, 1.7)	0.9 (0.7, 1.3)
12-18 y	4.7 (3.2, 7.0)	3.2 (2.4, 4.1)	2.0 (1.7, 2.5)	1.6 (1.4, 1.9)	1.3 (1.2, 1.4)	1.1 (1.1, 1.2)
5-11 y	1.9 (1.3, 2.8)	1.2 (0.9, 1.6)	1.0 (0.9, 1.2)	1.0 (0.8, 1.1)	0.9 (0.9, 1.0)	1.0 (0.9, 1.0)
2-4 y	ref	ref	ref	ref	ref	ref
Race/ethnicity				†	‡	‡
Black (non-Hispanic)	0.7 (0.5, 1.1)	0.9 (0.7, 1.1)	1.1 (0.9, 1.3)	1.3 (1.1, 1.5)	1.5 (1.4, 1.7)	1.8 (1.6, 1.9)
Hispanic	0.7 (0.4, 1.1)	0.8 (0.5, 1.1)	1.1 (0.8, 1.4)	1.1 (0.9, 1.3)	1.2 (1.1, 1.4)	1.3 (1.2, 1.4)
Other	0.9 (0.5, 1.7)	1.0 (0.8, 1.5)	1.0 (0.7, 1.3)	1.1 (0.8, 1.3)	1.0 (0.9, 1.2)	1.1 (1.0, 1.3)
Missing	1.6 (0.6, 4.1)	1.3 (0.6, 2.8)	0.9 (0.4, 1.7)	0.8 (0.4, 1.3)	0.8 (0.6, 1.1)	0.9 (0.7, 1.2)
White (non-Hispanic)	ref	ref	ref	ref	ref	ref
Principal payer				†	‡	‡
Public	0.9 (0.6, 1.2)	0.9 (0.7, 1.2)	1.1 (0.9, 1.3)	1.2 (1.0, 1.3)	1.3 (1.2, 1.4)	1.3 (1.2, 1.4)
Self-pay/no charge	0.4 (0.1, 1.3)	0.4 (0.2, 1.1)	0.7 (0.4, 1.2)	0.7 (0.5, 1.0)	0.8 (0.7, 1.0)	0.9 (0.8, 1.1)
Other	0.7 (0.3, 1.5)	0.7 (0.4, 1.3)	1.0 (0.7, 1.5)	1.1 (0.8, 1.5)	1.1 (0.9, 1.3)	1.1 (0.9, 1.2)
Missing	0.5 (0.2, 1.7)	0.8 (0.4, 1.7)	0.9 (0.5, 1.7)	1.2 (0.8, 2.0)	1.3 (0.9, 1.8)	1.4 (1.0, 1.9)
Private	ref	ref	ref	ref	ref	ref
CCC patient	2.4 (1.7, 3.4)‡	2.6 (2.0, 3.4)‡	1.9 (1.6, 2.3)‡	1.9 (1.6, 2.1)‡	1.6 (1.5, 1.8)‡	1.5 (1.4, 1.7)‡
Home disposition§	0.3 (0.1, 0.5)‡	0.4 (0.2, 0.7)‡	0.5 (0.3, 0.7)‡	0.8 (0.5, 1.1)	0.8 (0.6, 1.0)*	0.8 (0.6, 0.9)*
Magnesium given	1.0 (0.7, 1.5)	0.9 (0.7, 1.2)	1.1 (0.9, 1.3)	1.1 (0.9,1.3)	1.2 (1.1, 1.4)‡	1.3 (1.2, 1.4)‡
ICU stay	0.4 (0.2,0.8)†	0.7 (0.5,1.1)	0.7 (0.5, 0.9)†	0.8 (0.7,0.9)†	0.9 (0.8,1.0)†	0.9 (0.8, 1.0)†
LOS			*	†	‡	‡
5+ d	0.5 (0.3, 1.1)	0.9 (0.6, 1.4)	1.3 (1.0, 1.8)	1.4 (1.1, 1.7)	1.6 (1.4, 1.8)	1.6 (1.5, 1.8)
3-4 d	1.1 (0.8, 1.6)	1.1 (0.8, 1.5)	1.3 (1.1, 1.6)	1.3 (1.1, 1.4)	1.4 (1.3, 1.6)	1.5 (1.3, 1.6)
2 d	0.9 (0.6, 1.2)	1.0 (0.8, 1.3)	1.1 (0.9, 1.3)	1.2 (1.0, 1.3)	1.3 (1.2, 1.4)	1.3 (1.2, 1.4)
1 d	ref	ref	ref	ref	ref	ref
Prior year admission	2.0 (1.4, 2.7)‡	2.7 (2.1, 3.3)‡	2.9 (2.5, 3.4)‡	3.5 (3.1, 3.9)‡	3.5 (3.3, 3.8)‡	3.6 (3.4, 3.8)‡
Hospital¶	1.4 (1.3, 2.1)‡	1.3 (1.2, 1.8)†	1.4 (1.3, 1.7)‡	1.4 (1.3, 1.6)‡	1.3 (1.3, 1.5)‡	1.3 (1.3, 1.5)‡

LOS, length of stay.
*$P \leq .05$.
†$P \leq .01$.
‡$P \leq .001$.
§Reference group are patients discharged to a post-acute care facility and patients discharged to home with home nursing.
¶Shown are OR of readmission for patients in hospitals with rehospitalization rates that are 1 SD above the mean (exponentiated square root of the hospital-level variance component).

variation in case-mix-adjusted rehospitalization rates across hospitals exists at all time intervals out to 1 year from the index admission. A substantial proportion of asthma rehospitalizations could be avoided if all hospitals were able to achieve rates equivalent to the best performing hospitals.

The 30-day asthma repeat admission rate in our study (<2%) is similar to the rate reported in a recent study of children's hospitals.[14] Children hospitalized with asthma may be less likely to have an immediate rehospitalization because inpatient care is highly effective; most children's hospitals report near perfect performance on 2 of the 3 inpatient asthma care processes endorsed by the Joint Commission, use of inpatient bronchodilators and systemic steroids.[14] Readmissions soon after discharge may be infrequent simply because of the episodic nature of the disease or efforts to ensure the receipt of discharge transitional care medications before they leave the hospital.[9]

By 365 days, the asthma rehospitalization rate in our study reached 17% and year-to-year correlation was highest for the 365-day hospital rate rank. This suggests that longer term rehospitalization rates may be relatively consistent from year to year in a given hospital. The weaker correlation of shorter-interval readmissions over time is likely to reflect poorer reliability because of smaller sample sizes per hospital.[15] Given this finding, 30-day asthma readmission

Table III. Pediatric asthma rehospitalization variation across hospitals and potential rehospitalizations avoided

Rehospitalization time interval	Adjusted rehospitalization rates*		Rehospitalizations avoided if all hospitals had rates ≤10th percentile	
	Overall† median % (IQR)*	10th percentile benchmark %*	Rehospitalizations avoided	Percentage avoided
7 d	0.4 (0.2,0.7)	0.2	123	59.1%
15 d	0.7 (0.6,1.1)	0.3	249	65.7%
30 d	1.6 (1.2,2.3)	1.0	384	46.8%
60 d	3.5 (2.5,4.4)	1.8	901	53.4%
180 d	9.2 (7.8,11.3)	5.8	1934	43.2%
365 d	15.8 (12.3,18.9)	10.9	2780	36.6%

*Adjusted for age and the presence of 1 or more CCC in a generalized linear mixed logistic regression.
†Reflects overall median including those hospitals in the 10th percentile.

rankings would likely be more stable if they were pooled over multiple years.

The higher rate of rehospitalization at 365 days may be explained by the increased difficulty of preventing longer-term asthma exacerbations. Although well-orchestrated transitions from inpatient to outpatient care are essential to preventing short-term readmission, preventing longer-term rehospitalization requires an even greater focus on timely and effective outpatient and community care. Outpatient and community care may not be equally accessible or effective for children of all demographic backgrounds.[16] This may explain why rehospitalization rates varied significantly by patients' race/ethnicity and insurance type at 60 days and beyond.

Although longer-term rehospitalizations may be harder to prevent, a number of interventions have demonstrated significant reductions in rehosptalization beyond 30 days. Two randomized clinical trials of interventions focused on the discharge transition with dedicated asthma nurse specialists demonstrated significant repeat hospitalization reduction beyond 6 months after the index hospitalization.[6,7] A clinical trial of an intervention that included frequent outpatient follow-up, culturally appropriate asthma education, an asthma self-care plan, and psychosocial support services demonstrated reductions in adult asthma rehospitalizations at 6 months.[17] Studies involving pediatric community asthma initiatives with home visits and educational components have reduced asthma hospitalization and rehospitalization rates.[18,19] These interventions were effective in their primary goal; however, such interventions can be resource-intensive and may be best suited for those patients at highest risk of rehospitalization.

We observed 3 characteristics of patients who were consistently associated with increased repeat admission likelihood at each interval: asthma admission in the prior year, age 12-18 years, and diagnosis of a CCC. Prior year asthma admission is well established as a risk factor for rehospitalization and may reflect a number of unmeasured factors, such as higher disease severity, lower access to care, and substandard disease control.[12] In contrast to our findings, previous studies have demonstrated higher rates of asthma rehospitalization in younger children than older children.[20,21] These studies included children aged <2 years, who may have higher risk for repeat admission but for whom the diagnosis of asthma often overlaps with bronchiolitis or other respiratory illnesses characterized by wheezing. Adolescents have been shown to have higher rates of controller non-adherence and a greater proportion of "difficult to control" asthma,[22] which likely contributed to their higher repeat hospitalization rates in the current study. Diagnosis of a CCC has been previously demonstrated as a risk factor for rehospitalization.[11]

In our multivariate model, ICU stay was associated with a lower readmission odds at all intervals except 15 days. Higher severity of chronic illness and more comorbid illness likely contribute to the elevated odds of readmission of ICU patients in bivariate analysis. Controlling for these in our multivariate model may have reduced the influence of these factors on readmission odds. A lower adjusted odds of readmission may result from targeted discharge and outpatient interventions to ICU patients.

We observed significant variation in asthma rehospitalization rates across hospitals at all time intervals. We were unable to determine how much of this variation was due to substandard quality of care. Thresholds for asthma hospitalization may differ across communities[23] and these thresholds may influence rehospitalization rates. Asthma hospitalization rates are influenced by local provider adherence to National Asthma Education and Prevention Program guidelines and patient adherence to controller medications.[24] These factors may also influence rehospitalization rates.[25] Alternatively, asthma severity may vary intrinsically by patient genetic or biological makeup or extrinsically by local environmental conditions,[26,27] making the disease more difficult to treat and readmissions more difficult to avoid in some patients and communities regardless of the quality of care they receive. Furthermore, the relationship between readmission and health care quality is complex.[28] Other health system and ecological factors, such as relative access to primary care, school-based care, pharmacies, or hospitals may contribute to observed hospital variation in readmission rates.

Lastly, our estimates suggest that nearly 37% of repeat hospitalizations over the course of a year might have been avoided if all hospitals and their surrounding health systems had rates similar to the best performing amongst them. Although reducing rates to the level of the hospitals performing at the 10th percentile may seem an ambitious target, this goal has been used for performance benchmarking.[13] Extrapolating cost savings from such an analysis does not include costs of interventions to reduce repeat admissions or shifts in outpatient and emergency department costs; it also does not include information on quality of life for patients and families. Therefore, our results should not be interpreted as expected total savings.

Our analysis was limited to repeat hospitalizations at the same children's hospital within the PHIS dataset (ie, readmissions to different hospitals could not be measured) and so may underestimate true rates. One study of adult heart failure patients demonstrated that nearly 20% of readmissions occurred at institutions other than the location of index hospitalization.[29] The proportion of children rehospitalized at other institutions is unknown; however, children may be more likely to have their inpatient care centralized within 1 institution—especially those children with more severe asthma who are more likely to experience a readmission. Future empirical analyses of other datasets that link patient visits across different hospitals could clarify the magnitude of this phenomenon.

Our analysis did not control for the effect of multiple readmissions by the same individuals. In a post-hoc analysis, we revised our multivariate model to control for individual's random effects. Readmission odds and levels of significance, did not change, with the exception of female sex no longer being significantly associated with rehospitalization at 365 days.

Outpatient and community data, such as ambulatory visit rates, asthma medication adherence, asthma trigger exposures, and access to appropriate care, which may influence rehospitalization risk, are unavailable in PHIS. Also, our results may not be generalizable to community hospitals. Lastly, we focused our analysis on repeat admission specifically for asthma; although all-cause rehospitalization rates may be higher, they may include admissions that are not related to the prior admission.

Our study's findings have important implications regarding asthma rehospitalizations and the opportunity for care improvement. There is significant variation in asthma rehospitalization rates across children's hospitals that is not explained by case-mix differences in their patients. Asthma discharge and follow-up care processes, in addition to the hospital characteristics and community ecological factors, of institutions with relatively low rates of rehospitalization, should be studied further to identify the care attributes and system factors that contribute to short- and longer-term asthma rehospitalization risk in children. ■

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