Pediatric Readmissions After Hospitalizations for Lower Respiratory Infections

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BACKGROUND AND OBJECTIVE: Lower respiratory infections (LRIs) are among the most common reasons for pediatric hospitalization and among the diagnoses with the highest number of readmissions. Characterizing LRI readmissions would help guide efforts to prevent them. We assessed variation in pediatric LRI readmission rates, risk factors for readmission, and readmission diagnoses.

METHODS: We analyzed 2008–2009 Medicaid Analytic eXtract data for patients <18 years of age in 26 states. We identified LRI hospitalizations based on a primary diagnosis of bronchiolitis, influenza, or community-acquired pneumonia or a secondary diagnosis of one of these LRIs plus a primary diagnosis of asthma, respiratory failure, or sepsis/bacteremia. Readmission rates were calculated as the proportion of hospitalizations followed by ≥1 unplanned readmission within 30 days. We used logistic regression with fixed effects for patient characteristics and a hospital random intercept to case-mix adjust rates and assess risk factors.

RESULTS: Of 150,990 LRI hospitalizations, 8233 (5.5%) were followed by ≥1 readmission. The median adjusted hospital readmission rate was 5.2% (interquartile range: 5.1%–5.4%), and rates varied across hospitals (P < .0001). Infants (patients <1 year of age), boys, and children with chronic conditions were more likely to be readmitted. The most common primary diagnoses on readmission were LRIs (48.2%), asthma (10.0%), fluid/electrolyte disorders (3.4%), respiratory failure (3.3%), and upper respiratory infections (2.7%).

CONCLUSIONS: LRI readmissions are common and vary across hospitals. Multiple risk factors are associated with readmission, indicating potential targets for strategies to reduce readmissions. Readmission diagnoses sometimes seem related to the original LRI.
Because factors other than health care quality influence readmissions, including natural disease course, family and community supports, and sociodemographic factors, using readmission rates as a quality measure is controversial.\(^1\)\(^-\)\(^3\) Nevertheless, reducing hospital readmissions has become a widespread quality improvement goal. Readmissions are generally undesirable because they disrupt the lives of patients and families,\(^4\)\(^-\)\(^7\) expose patients to the risk of harms associated with hospitalization,\(^8\)\(^-\)\(^12\) and are costly.\(^9\)\(^-\)\(^12\) Hain et al\(^13\) found that 20% of pediatric 15-day readmissions “were more likely preventable... by changing care or discharge planning during the index admission.” Using chart review and interviews with parents, adolescent patients, and providers, Toomey et al\(^14\) determined that 29.5% of pediatric 30-day readmissions were potentially preventable.

As part of the Pediatric Quality Measures Program under the Centers for Medicare & Medicaid Services and the Agency for Healthcare Research and Quality, we developed a publicly available measure, endorsed by the National Quality Forum, to assess readmissions after hospitalization for lower respiratory infections (LRIs).\(^15\)\(^,\)\(^16\)

We focused on LRIs (bronchiolitis, influenza, and community-acquired pneumonia) because these conditions are prevalent in children and result in substantial morbidity and mortality. Bronchiolitis due to respiratory syncytial virus is the top reason for hospitalization of children aged <1 year.\(^17\) Pneumonia and influenza are among the top 10 reasons for hospitalization in children ≤17 years of age and the top 10 causes of death in children aged 29 days to 9 years.\(^18\)\(^,\)\(^19\)

Few studies have investigated readmissions after pediatric LRI hospitalizations, but findings to date indicate that such readmissions are common and account for a large proportion of overall pediatric readmissions.\(^20\)\(^,\)\(^21\) Using our LRI readmission measure, we examined readmissions after LRI acute care hospitalizations in a large sample of Medicaid-insured children. We assessed whether readmission performance varied across hospitals. We also examined risk factors for readmissions and determined the most common primary diagnoses on readmission, thus identifying potential targets for strategies to reduce LRI readmissions.

**METHODS**

**Data and Study Population**

We used 2008–2009 Medicaid Analytic eXtract inpatient claims data for 26 states (Supplemental Information),\(^22\) selected based on the quality and completeness of encounter data. We evaluated hospitalizations with discharge dates from December 1, 2007 to November 30, 2009. Our study population consisted of patients aged <18 years at the time of the initial LRI admission, hereafter referred to as the index admission. The Boston Children’s Hospital Institutional Review Board approved the study with a waiver of informed consent.

**Definitions and Outcome Measures**

Our readmission measure identifies LRI admissions as those with either (1) a primary *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) diagnosis code for bronchiolitis, influenza, or community-acquired pneumonia, or (2) a secondary diagnosis code for one of these LRIs plus a primary diagnosis code for asthma, respiratory failure, or sepsis/bacteremia (Supplemental Information). We compiled diagnosis codes for identifying LRI admissions by reviewing the literature for studies that used ICD-9-CM codes for LRI case ascertainment,\(^23\)\(^-\)\(^47\) as well as by manually reviewing ICD-9-CM code sets. We define a readmission as the first unplanned admission within 30 days of discharge from an LRI index hospitalization, where the readmission occurred at either the index hospital or a different hospital. To make observations independent and keep readmission rates from being dominated by relatively few patients with multiple readmissions within short time periods, repeated LRI admissions are counted as new index admissions only if they occurred >30 days after discharge from the previous index admission. If an inpatient claim has the same date for admission and discharge and this date was the same as the discharge date for an index admission, the claim is considered to be part of the index admission rather than indicative of a readmission. If a patient was transferred from 1 hospital to another during an index admission, records from the hospitals are combined and evaluated as a single index admission, and a potential subsequent readmission is attributed to the final hospital.

Our primary outcome measure was the hospital-level 30-day LRI readmission rate during the 2-year study period, defined as the number of LRI index admissions followed by ≥1 readmission within 30 days, divided by the total number of LRI index admissions at a given hospital during the study period.

**Exclusion Criteria**

The measure excludes admissions with missing or inconsistent data for key variables, including patient identifier; sex; dates of birth, admission, and discharge; diagnosis and procedure codes; disposition status; and hospital type. We include only hospitalizations at general acute care hospitals, defined as including both children’s hospitals and non–children’s hospitals with a pediatric ward. We exclude records from specialty (eg, those focused on specific conditions, such as burns) and...
non–acute care (eg, rehabilitation) hospitals. We exclude index admissions during which a patient died or left against medical advice.

The measure excludes planned admissions, defined as those for a planned procedure or for chemotherapy (Supplemental Information), from readmissions based on the rationale that planned admissions are part of a patient’s intended course of care and are thus less likely to be related to health system quality. To identify planned procedure admissions, we developed an algorithm by asking pediatric clinicians in 14 procedure-oriented specialties to review procedures typically performed by their specialty and to indicate which procedures are planned >80% of the time and could serve as the primary reason for a hospitalization. Admissions for which the primary procedure coded was 1 of these procedures are excluded from readmissions.

In addition, the measure excludes hospitalizations for obstetric care, birth of healthy newborns, and mental health conditions (see Supplemental Information for detailed definitions). We exclude obstetric hospitalizations because obstetric care generally does not fall within the purview of pediatrics. We exclude hospitalizations for the birth of healthy newborns because these patients, unlike others, are not hospitalized for management of disease. Mental health hospitalizations are excluded because we found a negative correlation between readmission performance for mental health conditions and for other conditions (hospitals with high readmission rates for mental health hospitalizations tend to have low readmission rates for hospitalizations for other conditions and vice versa), suggesting that readmission performance for mental health conditions should be evaluated separately from performance for other conditions.

Case-Mix Adjustment and LRI Readmission Risk Factors

The measure adjusts readmission rates for age, sex, and chronic conditions at the index admission because distributions of these characteristics vary across hospitals, and although they are associated with readmission risk, they are independent of hospital quality of care.40 Age is specified by using developmentally relevant categories of <1, 1 to 4, 5 to 7, 8 to 11, and 12 to 17 years. We identify chronic conditions using the Agency for Healthcare Research and Quality Chronic Condition Indicator (CCI) system, which classifies ICD-9-CM diagnosis codes as chronic or acute and places each code into 1 of 18 mutually exclusive categories (organ systems, disease categories, or other categories) (Supplemental Information). The case-mix adjustment model incorporates a binary variable for each CCI category, indicating whether a patient has ≥1 chronic condition in that category. We exclude the category “Complications of pregnancy, childbirth, and the puerperium” because exclusion of obstetric hospitalizations leaves few or no patients with obstetric diagnosis codes, which could create model-fitting issues for the case-mix adjustment model. In addition, we model the effect of multiple types of chronic conditions on readmission risk by including a variable indicating the number of CCI categories in which a patient had ≥1 chronic condition. We use categories of 0 or 1, 2, 3, or ≥4 because few index admissions have diagnoses in >4 categories. We assessed each of the case-mix adjustment variables (age, sex, CCI category, and CCI count) as potential risk factors for readmission after hospitalization for LRI.

Because the purpose of the measure is assessment of health care quality, the measure does not adjust readmission rates for factors that could be related to both readmission risk and quality of care, such as length of stay or regional variation in readmission rates.

Analyses

To compare the frequency of readmission after hospitalizations with a primary diagnosis of an LRI versus hospitalizations with other primary diagnoses, we calculated the number of readmissions in our total sample for each index admission primary diagnosis. Because we wished to compare readmissions after hospitalizations for LRI versus readmissions after hospitalizations for other conditions, we performed this analysis by using all index hospitalizations for our study cohort rather than just LRI index hospitalizations. Because it was not feasible to develop a complex case definition for each other possible condition, for this analysis only, we did not use the full LRI measure case definition (detailed above); rather, we evaluated all index hospitalizations based simply on their primary diagnosis code, identifying LRI index hospitalizations as those with a primary diagnosis code for an LRI.

To identify the most common reasons for readmission after an LRI index admission, we determined the most frequent primary diagnosis codes on readmission. To case-mix adjust readmission rates and assess risk factors for readmission, we used a 2-level mixed-effects logistic regression model with fixed effects for patient-level variables and a random intercept for each hospital. The model estimated 3 types of parameters. The coefficients of patient demographic and clinical characteristics represent the influence of these characteristics on predicted probabilities of readmission for an individual patient. The random intercept estimates for each hospital correspond to greater or lesser adjusted probability of readmission, after controlling for patient-level fixed effects, for patients discharged from each hospital. The estimated variance of the hospital random effects summarizes the amount of variation among the intercepts for different
hospitals and hence the amount of variation in adjusted readmission rates across hospitals, at least some of which may have been due to variation in health system quality. A 2-sided \( P < .05 \) was used as the criterion for statistical significance for this analysis. Finally, for hospitals with higher pediatric volumes (≥50 index admissions for any condition and ≥50 LI index admissions over the 2-year study period), we determined the number of hospitals with adjusted readmission rates significantly better or worse than the overall unadjusted readmission rate across hospitals (ie, hospitals whose readmission rate confidence intervals did not overlap with the overall unadjusted readmission rate).

**RESULTS**

**Patient and Hospital Characteristics**

Infants (<1 year of age) and young children (1–4 years of age) comprised the age groups with the largest share (47.0% and 36.9%, respectively) of 150,590 total LI index admissions (Table 1). The majority of index admissions (89.6%) were for patients with no chronic conditions or chronic conditions in only 1 body system. Approximately one-quarter of index admissions (23.6%) occurred at children’s hospitals. Among the 1929 hospitals, 4.1% were children’s hospitals and 6.3% were teaching hospitals (Table 2). Approximately one-third of hospitals were in urban locations.

**Readmission Rates and Variation**

Applying the measure definition for an LI index admission (ie, a primary diagnosis of bronchiolitis, influenza, or pneumonia, or a secondary diagnosis of one of these LRIs with a primary diagnosis of asthma, respiratory failure, or sepsis/bacteremia), 8233 of 150,590 total LI index admissions were followed by ≥1 readmission (Fig 1). The overall unadjusted LI readmission rate across all hospitals was thus 5.5%. Adjusted hospital-level readmission rates ranged from 3.8% to 8.8%, with a median adjusted hospital-level readmission rate of 5.2% (interquartile range: 5.1%–5.4%). Adjusted readmission rates varied significantly across hospitals (\( P < .0001 \)). The estimated SD of the hospital random effects offers a sense of how much a patient’s readmission risk varied depending on which hospital provided his or her care; our results indicated that a patient whose probability of readmission was 5.2% (the overall average) at a hospital of median quality would have had a predicted probability of readmission of 6.5% if cared for at a hospital with a random effect 1 SD above the mean, whereas the same patient would have had a predicted probability of readmission of 4.2% at a hospital with a random effect 1 SD below the mean. Among the 338 hospitals with higher pediatric volume (≥500 index admissions for any condition and ≥50 LI index admissions), we found that 2 had readmission rates significantly better and 5 had rates significantly worse than the overall unadjusted readmission rate across all hospitals (Fig 2).

**Index Admission Primary Diagnoses Associated With the Highest Number of Readmissions**

LI was the index admission primary diagnosis with the highest number (6711) of 30-day readmissions, followed by asthma (1933), epilepsy and convulsions (1632), device- and procedure-related complications (1597), and anemia (1585).

**Diagnoses on Readmission**

LI was the primary diagnosis for 48.2% of LI readmissions. The next most common primary readmission diagnoses were asthma (10.0%), fluid/electrolyte disorders (3.4%), respiratory failure (3.3%), and upper respiratory infections (2.7%).

**Risk Factors for LI Readmission**

In our multivariate case-mix adjustment model, age had a nonlinear statistically significant relationship with LI readmission risk (Table 3). Boys had a small but statistically significant increase in readmission risk (Table 3). Having ≥1 chronic condition in a CCI category was also associated with increased readmission risk for most categories, including neoplasms, neurologic disorders, and congenital anomalies. The odds ratios for having chronic conditions in 3 or ≥4 categories were <1, indicating that the effects of having chronic conditions in multiple CCI categories were less than the additive effects of conditions in individual categories. For example, suppose that subject

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**TABLE 1 Patient Characteristics (Total \( N = 150,590 \))**

<table>
<thead>
<tr>
<th>Patient Characteristic</th>
<th>Index Admissions, ( n (%) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td></td>
</tr>
<tr>
<td>&lt;1</td>
<td>70,781 (47.0)</td>
</tr>
<tr>
<td>1–4</td>
<td>55,532 (36.9)</td>
</tr>
<tr>
<td>5–7</td>
<td>11,498 (7.6)</td>
</tr>
<tr>
<td>8–11</td>
<td>6,962 (4.6)</td>
</tr>
<tr>
<td>12–17</td>
<td>5,817 (3.9)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Girl</td>
<td>65,417 (43.4)</td>
</tr>
<tr>
<td>CCI count</td>
<td></td>
</tr>
<tr>
<td>0 or 1 body system</td>
<td>134,878 (88.6)</td>
</tr>
<tr>
<td>2 body systems</td>
<td>100,335 (6.7)</td>
</tr>
<tr>
<td>3 body systems</td>
<td>3732 (2.5)</td>
</tr>
<tr>
<td>≥4 body systems</td>
<td>1,943 (1.3)</td>
</tr>
<tr>
<td>Race/ethnicity</td>
<td></td>
</tr>
<tr>
<td>Asian/Pacific Islander</td>
<td>1,954 (1.4)</td>
</tr>
<tr>
<td>African American</td>
<td>32,070 (23.0)</td>
</tr>
<tr>
<td>Latino</td>
<td>46,827 (33.4)</td>
</tr>
<tr>
<td>Mixed</td>
<td>1,285 (0.9)</td>
</tr>
<tr>
<td>Native American</td>
<td>7,230 (5.2)</td>
</tr>
<tr>
<td>White</td>
<td>56,606 (38.2)</td>
</tr>
</tbody>
</table>

**TABLE 2 Hospital Characteristics (Total \( N = 1929 \))**

<table>
<thead>
<tr>
<th>Hospital Characteristic</th>
<th>Hospitals, ( n (%) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children’s hospital</td>
<td>79 (4.1)</td>
</tr>
<tr>
<td>Teaching hospital</td>
<td>118 (6.3)</td>
</tr>
<tr>
<td>Rural/urban location</td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>662 (34.4)</td>
</tr>
<tr>
<td>Suburban</td>
<td>97 (5.0)</td>
</tr>
<tr>
<td>Large town</td>
<td>408 (21.2)</td>
</tr>
<tr>
<td>Small town</td>
<td>502 (26.1)</td>
</tr>
<tr>
<td>Rural</td>
<td>255 (13.2)</td>
</tr>
</tbody>
</table>

\( a \) Rural/urban location could not be determined for 5 hospitals.
1 had conditions in organ systems A, B, and C, whereas subject 2 only had conditions in organ system A, subject 3 only had conditions in organ system B, and subject 4 only had conditions in organ system C, the combined impact of subject 1’s conditions on his or her readmission risk may have been smaller than the sum (impact of subject 2’s conditions + impact of subject 3’s conditions + impact of subject 4’s conditions).

**DISCUSSION**

Analyzing a large, multistate sample of Medicaid-insured children cared for at both children’s and non–children’s hospitals, we found a median adjusted hospital-level LRI readmission rate of 5.2% (interquartile range: 5.1%–5.4%). Using as a comparator the overall unadjusted readmission rate across hospitals of 5.5%, only 7 of the 338 high-volume hospitals were outliers. However, readmission rates varied significantly across hospitals. Although our study could not offer insight into the preventability of readmissions and thus whether the hospital-level rate of 5.2% was higher than it should have been, the presence of significant variation suggests that at least some hospitals have room to improve their readmission performance for patients with LRIs. We also found that LRIs are the index admission diagnosis followed by the greatest number of 30-day readmissions, indicating that efforts to reduce LRI readmissions, to the extent that some of them could be prevented, may be a worthwhile focus for reducing pediatric readmissions overall.

For 48.2% of readmissions after an LRI index admission, an LRI was also the primary diagnosis on readmission, with asthma and respiratory failure among the next most common
readmission diagnoses. These results suggest that some readmissions may have been related to the index admission (although related readmissions are not necessarily preventable; related readmissions could also reflect clinical fluctuations that are part of the natural disease course). At the same time, the occurrence of diagnoses other than LRI for just over half of readmissions suggests that some readmissions were unrelated to the index admission or that some index admission diagnoses were simply incorrect.

Infants and subjects with various types of chronic conditions were at greatest risk of readmission, perhaps reflecting that these populations are also at greatest risk of severe or complicated LRI. These patients may be the best target groups for efforts to decrease readmissions. Our study was not designed to determine definite strategies for preventing readmissions, but to the degree that some readmissions could be prevented, optimizing care during the initial admission may help to reduce readmissions. For example, implementation of a management algorithm for complicated pneumonia at a tertiary children’s hospital was associated with decreased readmissions without increased lengths of stay. One important set of interventions to improve inpatient LRI care may be strategies to avoid premature discharges. We do not propose increased lengths of stay regardless of clinical status as a solution to preventing readmissions. Rather, strategies such as standardized, evidence-based discharge criteria might help to prevent some patients from being discharged before they are ready while avoiding longer-than-necessary hospitalizations for others. Implementation of a clinical pathway for bronchiolitis was associated with a reduction in 14-day readmissions, seemingly due to improvements in discharge planning and achievement of explicit clinical outcomes before discharge. In addition to improvements in inpatient care, optimizing transitions and postdischarge care to prevent, promptly detect, and effectively address clinical worsening may also be key in preventing LRI readmissions. Recovery after a hospitalization for an LRI can take several days and require ongoing care by parents or other caregivers. Studies assessing the effectiveness and cost-effectiveness of interventions to reduce pediatric readmissions are still rare, but promising approaches have included 1-on-1 inpatient education and postdischarge support by telephone or clinic visit. Our finding of an overall unadjusted 30-day readmission rate of 5.5% after LRI index admissions was the same as the all-cause readmission rate reported by Bardach et al for pediatric respiratory disease (asthma, pneumonia, and bronchiolitis) hospitalizations in a multistate, all-payer sample of children admitted to children’s and non-children’s hospitals. A 30-day all-cause readmission rate of 7.7% was found by Neuman et al for patients hospitalized for pneumonia at 43 freestanding children’s hospitals, possibly reflecting the tendency of these institutions to care for children with greater severity of illness or underlying medical complexity. It remains true for LRI hospitalizations, as for other hospitalizations, that the “optimal” readmission rate is not known. Even if some readmissions could be prevented, others would be appropriate and unavoidable, and our study was not designed to distinguish among these possibilities. Our study was consistent with previous studies focusing on bronchiolitis and pneumonia readmissions in finding significant variation across hospitals in LRI readmission performance. Likewise, our results corresponded with those of previous investigations in demonstrating that younger children and those with chronic conditions are most at risk for LRI readmission. Among the strengths of our study was the inclusion of pediatric admissions from both children’s and
non–children’s hospitals in half of US states. Our data source, Medicaid claims, captured readmissions to any hospital rather than just the index hospital. However, the study also had several limitations. Because the latest data available to us were from 2008 to 2009, our findings do not reflect changes that may have occurred in LRI readmissions more recently, including possible reductions in readmission rates that may have resulted from increased focus on readmissions. In using claims data, we relied on ICD-9-CM codes for identification of index admissions, chronic conditions, conditions and procedures for exclusions, and diagnoses on readmission. ICD-9-CM codes offer limited detail regarding severity of illness, and they may not fully reflect a patient’s clinical picture. \(^5\) Furthermore, although our planned procedure algorithm was developed with input from clinical experts, it has not been externally validated. In addition, our use of Medicaid claims allowed us to examine readmissions for a potentially high-risk population,\(^6\) but it precluded evaluating the relationship between insurance status and readmission risk. We also lacked data to investigate other factors potentially associated with LRI readmission, including other socioeconomic factors, such as family income and parental/caregiver education level, and community factors, such as access to primary care.

**CONCLUSIONS**

Using a large sample of Medicaid-insured children hospitalized at children’s and non–children’s hospitals, we determined that LRI readmission rates vary across hospitals, suggesting that there is room for improvement for at least some hospitals. Readmissions could be a fruitful target for improving inpatient and postdischarge care for LRIs.

### TABLE 3 Risk Factors for LRI Readmission

<table>
<thead>
<tr>
<th>CCI count</th>
<th>OR (95% CI)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 or 1 body systems</td>
<td>Reference</td>
<td>—</td>
</tr>
<tr>
<td>2 body systems</td>
<td>1.00 (0.89–1.12)</td>
<td>.994</td>
</tr>
<tr>
<td>3 body systems</td>
<td>0.75 (0.62–0.90)</td>
<td>.002</td>
</tr>
<tr>
<td>≥4 body systems</td>
<td>0.38 (0.28–0.50)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

CI, confidence interval; OR, odds ratio. —. no P value.

\(^a\) The reference group for each CCI variable is no condition in the body system.

\(^b\) We excluded the CCI variable for body system 11, “Complications of pregnancy, childbirth, and the puerperium,” because patients who have a primary diagnosis code for an obstetric condition or any diagnosis or procedure code for delivery are excluded from the cohort.

**ABBREVIATIONS**

CCI: Chronic Condition Indicator  
ICD-9-CM: *International Classification of Diseases, Ninth Revision, Clinical Modification*  
LRI: lower respiratory infection

and agree to be accountable for all aspects of the work in ensuring questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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