RESEARCH ARTICLE

Length of Stay and Hospital Revisit After Bacterial Tracheostomy–Associated Respiratory Tract Infection Hospitalizations

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ABSTRACT

OBJECTIVES: To identify factors associated with longer length of stay (LOS) and higher 30-day hospital revisit rates for children hospitalized with bacterial tracheostomy–associated respiratory tract infections (bTARTIs).

METHODS: This was a multicenter, retrospective cohort study using administrative data from the Pediatric Health Information System database between 2007 and 2014 of patients 30 days to 17 years old with a principal discharge diagnosis of bTARTI or a principal discharge diagnosis of bTARTI symptoms with a secondary diagnosis of bTARTI. Primary outcomes of LOS (in days) and 30-day all-cause revisit rates (inpatient, observation, or emergency department visit) were analyzed by using a 3-level hierarchical regression model (discharges within patients within hospital).

RESULTS: We included 3715 unique patients and 7355 discharges. The median LOS was 4 days (interquartile range: 3–8 days), and the 30-day revisit rate was 30.5%. Compared with children 1 to 4 years old, children aged 30 days to 12 months had both longer LOS (adjusted length of stay [aLOS] = +0.9 days; 95% confidence interval [CI]: 0.6 to 1.3) and increased hospital revisit risk (adjusted odds ratio [aOR] = 1.5; 95% CI: 1.3 to 1.7). Other factors associated with longer LOS included public insurance (aLOS = +0.5 days; 95% CI: 0.2 to 0.8), 3 or more complex chronic conditions (CCCs), mechanical ventilation (acute or chronic), and empirical anti-*Pseudomonas aeruginosa* antibiotics (aLOS = +0.6 days; 95% CI: 0.3 to 0.9). Other factors associated with 30-day revisit included 4 or more CCCs (aOR = 1.3; 95% CI: 1.1 to 1.6) and chronic ventilator dependency (aOR = 1.1; 95% CI: 1.0 to 1.3).

CONCLUSIONS: Ventilator-dependent patients <12 months old with at least 4 CCCs are at highest risk for both longer LOS and 30-day revisit after discharge for bTARTIs. They may benefit from bTARTI prevention strategies and intensive care coordination while hospitalized.

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Over 4000 children undergo tracheostomy placement each year in the United States.[1,2] Because children with tracheostomy may be chronically colonized with bacteria and often have impaired airway clearance, they have high incidence rates of bacterial tracheostomy–associated respiratory tract infections (bTARTIs), such as bacterial pneumonia.[3] Despite this, there are no national guidelines for prevention, diagnosis, or treatment of bTARTIs in children with tracheostomies,[4–7] causing wide hospital-level care variations in the treatment of these patients.[8] Research using administrative data to study pediatric community-acquired pneumonia has revealed that younger age, public insurance, and the presence of a complex chronic condition (CCC) are associated with longer length of stay (LOS) and higher readmission rates.[9–11] However, no previous studies have identified risk factors for longer LOS and hospital revisit in pediatric patients admitted with bTARTIs. Identifying the factors that are associated with LOS and revisit rates may help providers to recognize patients who will benefit from interventions to mitigate these differences. Thus, the current study sought to examine factors associated with increased LOS and 30-day all-cause revisit rates for pediatric patients with tracheostomies admitted for bTARTIs.

METHODS

Data Source

We conducted a multicenter retrospective cohort study of patients discharged from 1 of 42 not-for-profit, freestanding children's hospitals contributing to the Pediatric Health Information System (PHIS) database between 2007 and 2014. This database represents 15% of the national and 46.4% of the children's hospital total volume, and it also provides deidentified resource use data that are subjected to a number of reliability and validity checks before being included in the database.[12] The study was reviewed and granted an exemption per 45 Code of Federal Regulations 46.101[b][4] by the Children's Hospital Los Angeles Institutional Review Board.

Patient Selection

We included children 30 days to 17 years of age at admission with an *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) code consistent with the presence of tracheostomy (V44.0, V55.0, 519.00, 519.01, 519.02, and 519.09) and either: (1) an ICD-9-CM code consistent with a principal diagnosis of bTARTI (eg, acute bacterial tracheitis); or (2) a principal diagnosis of a symptom of a respiratory tract infection (eg, cough) with a secondary diagnosis of a bTARTI. We identified pediatric patients with tracheostomy with ICD-9-CM codes used in previous studies of administrative data.[1,3,8,13] To identify bTARTIs, in addition to the ICD-9-CM codes previously used for bacterial community-acquired pneumonia,[14] we included codes for aspiration pneumonia (507.0, 507.8) and acute bacterial tracheitis (464.1×), as used in previous studies (see Supplemental Table 4 for a complete list).[8] Principal diagnoses were categorized as (1) bacterial pneumonia, (2) bacterial tracheitis, (3) aspiration pneumonia, and (4) other (eg, symptom of respiratory tract infections, such as viral pneumonia (Supplemental Table 4).

We excluded the following: (1) any patient hospitalized over 30 days, because this represented an extreme outlier in the entire population before applying any exclusion criteria; (2) any patient transferred from an inpatient status at an outside hospital given our interest in LOS as an outcome ($n = 1278$); (3) any patient who did not receive antibiotics within 48 hours of admission, to minimize the chance of including patients not initially admitted with a bTARTI but who developed one later during the hospitalization ($n = 280$); and (4) any discharge that ended in the patient's death ($n = 40$; $<0.1\%$ of the original sample), because these patients could not have a subsequent revisit.

Outcomes

Our primary outcomes of interest were discharge LOS and postdischarge 30-day all-cause revisit, defined as any hospital readmission to the inpatient unit, readmission to the observation unit, or an emergency department visit. We chose to examine all-cause revisit, rather than hospital readmission or respiratory infection-specific readmission, because it represents urgent hospital resource use, even if not tied to original bTARTI hospitalization, and because it is difficult to assess if the revisit was related to the index hospitalization by using administrative data alone.

Covariates

Demographic covariates of interest included admission age (categorized as 30 days–12 months, 1–4 years, 5–12 years, and 13–17 years), race and/or ethnicity (categorized as non-Hispanic white, non-Hispanic black Hispanic, and other), and payer status (categorized as public versus other). Medical covariates included individual CCCs (as defined by Feudtner et al's[15] classification system), gastrostomy tube status (ICD-9-CM procedure codes 43.1× and 97.02, diagnosis codes V44.1, V55.1, and 536.4×),[16] and chronic ventilator dependency (presence of an ICD-9-CM code of V46.1×). The ventilator dependency and mechanical ventilation variables were collapsed into a single variable because of multicollinearity; patients were then categorized as having (1) chronic ventilator dependence, (2) acute ventilator use, or (3) no ventilation use. We also identified receipt of antibiotics targeting *P aeruginosa* on hospital day 0 or 1 (see Supplemental Table 5).

Statistical Methodology

The relationship between individual risk factors and outcome measures was first examined via bivariate logistic regression predicting revisit within 30 days through unadjusted odds ratios (95% confidence intervals [CIs]) and via bivariate linear regression examining LOS through unadjusted estimates measured in the number of days (95% CI). A hierarchical multivariate regression analysis was used to incorporate all risk factors that either significantly predicted 1 or both of the outcome measures in the bivariate analyses or had medical justification for inclusion in the model, while adjusting for all covariates. The final model was a 3-level, hierarchical multivariate model in which conditions unique to a patient's discharge or that

changed over time were modeled at level 1 (eg, comorbid conditions, patient age), demographic factors that were the same over time within the same patient were modeled at level 2 (eg, race), and factors common to all patients within the same hospital were modeled at level 3 (eg, region). This hierarchical framework allowed for the use of clustering groups to account for the variability explained at each of the levels while assessing outcomes. We reported adjusted length of stay (aLOS) change, in days, and reported adjusted odds ratios (aORs) for hospital revisit rates.

Eight additional multivariate, hierarchical models were run to supplement the final model and generate predicted values that revealed the relationship of the individual CCCs with LOS and readmission within 30 days. To allow the most accurate estimates of the unique effects of each CCC, these multivariate models were adjusted for all covariates but were run independently of other CCCs. In all analyses, we used 2-tailed tests with a significance level of 0.05. Data analyses were performed by using Mplus (version 7.11; Muthén and Muthén, Los Angeles, CA).

RESULTS

Discharge-Level Demographic Data

The sample consisted of 3715 unique patients and 7355 discharges across 42 hospitals. The median number of admissions per patient was 1 (interquartile range [IQR]: 1–2, range: 1–27) (Table 1). Over 12.4% of patients included had 3 or more discharges included in the data set. Of the discharges, 59% ($n = 4343$) were male and 38.6% ($n = 2839$) were non-Hispanic white. The majority of discharges had a public payer (73.3%; $n = 5391$). Nearly 74% ($n = 5422$) of discharges were associated with 3 or more CCCs. The most common CCCs included respiratory (100%; $n = 7355$), gastrointestinal (83.8%; $n = 6160$), and neuromuscular (52.4%; $n = 3856$) conditions. Discharges were associated with a high level of medical technology dependency, with 77.1% ($n = 5672$) of patients having gastrostomy tube dependency and nearly 32% ($n = 2346$) of patients having ventilator dependency. Primary discharge diagnoses were largely

TABLE 1 Demographic Characteristics of Pediatric Admissions for bTARTIs in the Study Population, Stratified by 30-Day Revisit Rate ($n = 3715$ Unique Patients)

Variable	Total Sample	Hospital Revisit Within 30 d	
		No	Yes
	7355 (100)	5113 (69.5)	2242 (30.5)
Discharge-level variables			
Admission age, y, median (IQR)	3 (1–9)	4 (2–9)	2 (1–7)
Infant, *n* (%)	860 (11.7)	465 (9.1)	395 (17.6)
Early childhood, *n* (%)	3300 (44.9)	2226 (43.5)	1074 (47.9)
Late childhood, *n* (%)	2240 (30.5)	1719 (33.6)	521 (23.2)
Adolescence, *n* (%)	955 (13.0)	703 (13.7)	252 (11.2)
Insurance, *n* (%)			
Public	5391 (73.3)	3697 (72.3)	1694 (75.6)
Private, self-pay, other, missing	1964 (26.7)	1416 (27.7)	548 (24.4)
CCCs			
Total no., median (IQR)	3 (2–4)	3 (2–4)	3 (2–4)
Respiratory, *n* (%)	7355 (100)	5113 (100)	2242 (100)
Gastrointestinal, *n* (%)	6160 (83.8)	4275 (83.6)	1885 (84.1)
Neuromuscular, *n* (%)	3856 (52.4)	2703 (52.9)	1153 (51.4)
Congenital, *n* (%)	2445 (33.2)	1672 (32.7)	773 (34.5)
Cardiovascular, *n* (%)	1228 (16.7)	782 (15.3)	446 (19.9)
Metabolic, *n* (%)	532 (7.2)	365 (7.1)	167 (7.4)
Renal, *n* (%)	486 (6.6)	307 (6.0)	179 (8.0)
Hematologic, *n* (%)	275 (3.7)	184 (3.6)	91 (4.1)
Oncological, *n* (%)	161 (2.2)	110 (2.2)	51 (2.3)
No. CCCs, *n* (%)			
1	450 (6.1)	318 (6.2)	132 (5.9)
2	1483 (20.2)	1051 (20.6)	432 (19.3)
3	3169 (43.1)	2247 (43.9)	922 (41.1)
4 or more	2253 (30.6)	1497 (29.3)	756 (33.7)
Other comorbidities, *n* (%)			
Gastrostomy tube	5672 (77.1)	3969 (77.6)	1703 (76.0)
Ventilator dependency	2346 (31.9)	1560 (30.5)	786 (35.1)
Disposition, *n* (%)			
Home without home nurse	5771 (78.5)	4042 (79.1)	1729 (77.1)
Other	1584 (21.5)	1071 (20.9)	513 (22.9)
Mechanical ventilation during admission, *n* (%)			
Chronic ventilator dependency	2281 (31.0)	1513 (29.6)	768 (34.3)
Mechanical ventilation only during admission	1498 (20.4)	1045 (20.4)	453 (20.2)
No mechanical ventilation	3576 (48.6)	2555 (50.0)	1021 (45.5)
Admission diagnosis, *n* (%)			
Bacterial pneumonia	2901 (39.4)	2105 (41.2)	796 (35.5)
Bacterial tracheitis	3573 (48.6)	2372 (46.4)	1201 (53.6)
Aspiration pneumonia	589 (8.0)	404 (7.9)	185 (8.3)
Other	292 (4.0)	232 (4.5)	60 (2.7)
LOS, d, median (IQR)	4 (3–8)	4 (3–8)	5 (3–8)
Admitted to ICU during hospitalization, *n* (%)	2688 (36.5)	1855 (36.3)	833 (37.2)
Anti-*Pseudomonas* antibiotic on hospital day 0–1, *n* (%)	5336 (72.5)	3725 (72.9)	1611 (71.9)

TABLE 1 Continued

Variable	Total Sample	Hospital Revisit Within 30 d	
		No	Yes
Patient-level variables, *n* (%)			
Sex			
Male	4343 (59.0)	2980 (58.3)	1363 (60.8)
Female	3012 (41.0)	2133 (41.7)	879 (39.2)
Race			
White	2839 (38.6)	1981 (38.7)	858 (38.3)
Black	1414 (19.2)	995 (19.5)	419 (18.7)
Hispanic	1893 (25.7)	1310 (25.6)	583 (26.0)
Other	1209 (16.4)	827 (16.2)	382 (17.0)
Hospital-level variables, *n* (%)			
Region			
West	1810 (24.6)	1266 (24.8)	544 (24.3)
Midwest	2142 (29.1)	1409 (27.6)	733 (32.7)
Northeast	886 (12.0)	604 (11.8)	282 (12.6)
South	2517 (34.2)	1834 (35.9)	683 (30.5)

bacterial pneumonia (39.4%; $n = 2901$) or bacterial tracheitis (48.6%; $n = 3573$). With respect to clinical care during the hospitalizations, 51.4% ($n = 3779$) of patients received mechanical ventilation at some point during their hospitalization and 36.5% ($n = 2688$) were admitted to an ICU at some point during their hospitalization. Over 72% ($n = 5336$) received empirical antibiotic coverage targeting *P aeruginosa*. Over 78% ($n = 5771$) were discharged from the hospital without home nursing.

Primary Outcomes

The median LOS for the entire cohort was 4 days (IQR = 3–8 days). When we analyzed the intraclass correlation for the hierarchical, multivariate linear regression model for LOS (Table 2), 83.4% of the variance in LOS was caused by experiences unique to each discharge, 11.2% within the patient level, and 5.4% within the hospital level. The 30-day all-cause revisit rate was 30.5% (95% CI: 29.4% to 31.5%). Of those with a revisit, 70.6% ($n = 1583$) had inpatient status, 4.4% ($n = 98$) had observation status, and 25% ($n = 561$) went to the emergency department. Variability in the hierarchical, multivariate logistic regression model for 30-day all-cause revisit was primarily caused by experiences unique to each discharge (92.3%), with the patient and hospital levels accounting for 6.8% and 0.9% of the variance, respectively (Table 3).

Demographic and Social Factors

In our hierarchical, multivariate analysis of factors associated with LOS (Table 2) and 30-day revisit (Table 3), when compared with patients with admission age of 1 to 4 years, those with admission age 30 days to 12 months had longer LOS (aLOS = +0.8 days; 95% CI: 0.5 to 1.2) and higher odds of revisit (aOR = 1.5; 95% CI: 1.3 to 1.7), whereas admission ages of 13 to 17 years were associated with longer LOS (aLOS = +0.7 days; 95% CI: 0.3 to 1.1) but lower odds of 30-day all-cause revisit (aOR = 0.8; 95% CI: 0.7 to 0.9). Public insurance was associated with increased LOS (aLOS = +0.5 days; 95% CI: 0.2 to 0.8) but with no difference in 30-day revisit odds. Other demographic factors, including sex and race and/or ethnicity, were not associated with LOS or hospital revisit.

Medical Covariates

On hierarchical analysis, 4 or more CCCs were associated with longer LOS (aLOS = +1.6; 95% CI: 1.1 to 2.1) and higher revisit odds (aOR = 1.3; 95% CI: 1.1 to 1.6). Chronic ventilator dependence, when compared with those not receiving mechanical ventilation during the hospitalization, was also associated with increased LOS (aLOS = +0.6 days; 95% CI: 0.3 to 0.9) and higher odds of 30-day revisit (aOR = 1.2; 95% CI: 1.04 to 1.3). Those receiving mechanical ventilation acutely during hospitalization had a longer LOS (aLOS = +1.8 days; 95% CI: 1.5 to 2.1) but showed no differences in 30-day revisit rates.

In supplementary hierarchical, multivariate analyses to assess the impact of individual CCCs on the 2 primary outcomes (Supplemental Tables 6 and 7), all CCCs except oncological conditions were associated with increased LOS (Fig 1). Neuromuscular (aLOS = +1 days; 95% CI: 0.8 to 1.3) and metabolic (aLOS = +1 day; 95% CI: 0.5 to 1.4) conditions showed the strongest associations. In contrast to the LOS analysis, only renal (aOR = 1.2; 95% CI: 1.1 to 1.4), cardiovascular (aOR = 1.1; 95% CI: 1.03 to 1.3), and neuromuscular (aOR = 1.1; 95% CI: 1.01 to 1.7) conditions were associated with increased odds of 30-day revisit (Fig 2).

Principal Diagnosis

Compared with bacterial pneumonia as a principal diagnosis, bacterial tracheitis was associated with shorter LOS (aLOS = −0.9; 95% CI: −1.1 to −0.6) but no difference in revisit odds, whereas a principal diagnosis categorized as other was associated with longer LOS (aLOS = +2.2; 95% CI: 1.7 to 2.8) and lower revisit odds (aOR = 0.8; 95% CI: 0.6 to 0.9). Those with a principal diagnosis of aspiration pneumonia had a longer LOS (aLOS = +0.9; 95% CI: 0.5 to 1.3) but showed no differences in revisit rate.

Hospital and Other Characteristics

Patients discharged from hospitals in the Northeast had a shorter LOS (reference group: West; aLOS: −1.5 days; 95% CI: −2.8 to −0.2) without any difference in 30-day revisit rate. Conversely, patients discharged from hospitals in the Midwest had higher 30-day revisit rates (reference group: West; aOR: 1.3; 95% CI: 1.03 to 1.6) but no differences in LOS. With respect to other hospitalization characteristics and association with LOS, admission to the ICU at some point during the hospitalization (aLOS = +2.2 days; 95% CI: 1.9 to 2.5) and patient empirical use of antibiotics that target *P aeruginosa* (aLOS = +0.6 days;

TABLE 2 Hierarchical, Multivariate Linear Regression of Factors Associated With LOS for Pediatric Patients Admitted With bTARTIs

Variable	Unadjusted Change in LOS (95% CI)	*P*	Adjusted Change in LOS (95% CI)	*P*
Age				
Infant, 30 d–12 mo	0.55 (0.18 to 0.94)	.004	0.81 (0.45 to 1.19)	<.001
Early childhood, 1–4 y	Ref	—	Ref	—
Late childhood, 5–12 y	0.63 (0.32 to 0.89)	<.001	0.28 (−0.002 to 0.54)	.052
Adolescence, 13–17 y	1.32 (0.92 to 1.74)	<.001	0.68 (0.29 to 1.07)	<.001
Male	−0.20 (−0.49 to 0.06)	.13	−0.18 (−0.44 to 0.07)	.08
Race				
White	Ref	—	Ref	—
Black	0.13 (−0.25 to 0.49)	.49	0.24 (−0.14 to 0.63)	.22
Hispanic	−0.01 (−0.34 to 0.36)	.97	−0.04 (−0.36 to 0.45)	.85
Other	0.39 (−0.05 to 0.77)	.07	0.25 (−0.15 to 0.64)	.26
Public insurance	0.61 (0.34 to 0.88)	<.001	0.50 (0.23 to 0.79)	.002
Total no. CCCs				
1	Ref	—	Ref	—
2	0.63 (0.13 to 1.08)	.01	0.23 (−0.26 to 0.75)	.37
3	1.53 (1.06 to 1.92)	<.001	0.87 (0.40 to 1.37)	.004
4 or more	2.52 (2.01 to 2.91)	<.001	1.59 (1.12 to 2.12)	<.001
Disposition: other than home without nursing	1.43 (1.17 to 1.76)	<.001	1.05 (0.73 to 1.36)	<.001
Mechanical ventilation during admission				
Chronic ventilator dependency	1.84 (1.55 to 2.13)	<.001	0.62 (0.32 to 0.90)	<.001
Mechanical ventilation only during admission	3.14 (2.82 to 3.48)	<.001	1.80 (1.47 to 2.14)	<.001
No mechanical ventilation	Ref	—	Ref	—
Principal diagnosis				
Bacterial pneumonia	Ref	—	Ref	—
Bacterial tracheitis	−1.09 (−1.35 to −0.83)	<.001	−0.88 (−1.13 to −0.63)	<.001
Aspiration pneumonia	0.67 (0.24 to 1.10)	<.001	0.86 (0.45 to 1.28)	<.001
Other	2.79 (2.26 to 3.40)	<.001	2.23 (1.69 to 2.81)	<.001
Admitted to ICU during hospitalization	3.17 (2.93 to 3.41)	<.001	2.18 (1.90 to 2.45)	<.001
Anti-*Pseudomonas* antibiotic, hospital day 0–1	0.88 (0.61 to 1.13)	<.001	0.57 (0.30 to 0.85)	<.001
Hospital region				
West	Ref	—	Ref	—
Midwest	−0.50 (−1.41 to 0.51)	.31	−1.17 (−2.39 to 0.05)	.06
Northeast	−0.51 (−1.54 to 0.58)	.36	−1.49 (−2.79 to −0.16)	.01
South	0.29 (−0.72 to 1.23)	.55	0.10 (−0.99 to 1.10)	.85
Hospital-level empirical anti-*Pseudomonas* antibiotic, % total admissions	1.35 (−0.36 to 2.97)	.16	1.56 (−0.76 to 3.82)	.15
No. cases, unit change per 100	−0.04 (−0.14 to 0.05)	.46	−0.04 (−0.16 to 0.07)	.44
Census, unit change per 100	0.12 (−0.34 to 0.56)	.61	0.02 (−0.48 to 0.55)	.93

—, not applicable.

95% CI: 0.3 to 0.9) were associated with longer LOS, but not 30-day revisit. Those discharged from the hospital and taken to a setting other than home with no home nursing had a longer LOS (aLOS = +1.1; 95% CI: 0.7 to 1.4) but showed no differences in revisit rates. Other hospital factors, such as hospital percentage use of empirical anti-*Pseudomonas* antibiotics, hospital average daily census, and number of bTARTI discharges were not associated with LOS or 30-day revisit.

DISCUSSION

In our multicenter study of a cohort of children hospitalized with bTARTIs, we have demonstrated that specific hospital and patient factors are associated with increased LOS and higher odds of 30-day all-cause revisit after hospitalization for a bTARTI, with most variation occurring at the discharge level. An admission age <12 months, 4 or more CCCs, and chronic ventilator dependency were

TABLE 3 Hierarchical, Multivariate Logistic Regression of Factors Associated With 30-Day All-Cause Hospital Revisit for Pediatric Patients Admitted With bTARTIs

Variables	Unadjusted Odds Ratio (95% CI)	*P*	aOR (95% CI)	*P*
Age				
Infant, 30 d–12 mo	1.49 (1.36 to 1.66)	<.001	1.49 (1.33 to 1.67)	<.001
Early childhood, 1–4 y	Ref	—	Ref	—
Late childhood, 5–12 y	0.74 (0.68 to 0.80)	<.001	0.71 (0.65 to 0.78)	<.001
Adolescence, 13–17 y	0.81 (0.72 to 0.89)	<.001	0.76 (0.68 to 0.86)	<.001
Male	1.07 (1.00 to 1.15)	.09	1.07 (1.00 to 1.16)	.07
Race				
White	Ref	—	Ref	—
Black	1.04 (0.93 to 1.19)	.54	1.04 (0.92 to 1.16)	.52
Hispanic	1.11 (0.97 to 1.24)	.09	1.09 (0.98 to 1.24)	.12
Other	1.04 (0.92 to 1.19)	.54	0.98 (0.88 to 1.12)	.71
Public insurance	1.09 (1.02 to 1.16)	.01	1.08 (0.99 to 1.18)	.07
Total no. CCCs				
1	Ref	—	Ref	—
2	0.99 (0.90 to 1.12)	.87	1.04 (0.88 to 1.32)	.67
3	0.97 (0.88 to 1.10)	.61	1.10 (0.96 to 1.38)	.22
4 or more	1.10 (0.99 to 1.23)	.07	1.29 (1.11 to 1.61)	<.001
Disposition, other than home without nursing	1.05 (0.98 to 1.14)	.15	1.01 (0.92 to 1.11)	.78
Mechanical ventilation during admission				
Chronic ventilator dependency	1.13 (1.03 to 1.21)	.004	1.16 (1.04 to 1.27)	.01
Mechanical ventilation during admission	1.03 (0.95 to 1.11)	.47	1.07 (0.96 to 1.19)	.22
No mechanical ventilation	Ref	—	Ref	—
Admission diagnosis				
Bacterial pneumonia	Ref	—	Ref	—
Bacterial tracheitis	1.13 (1.05 to 1.21)	<.001	1.08 (0.99 to 1.17)	.09
Aspiration pneumonia	1.13 (0.99 to 1.29)	.08	1.07 (0.94 to 1.22)	.28
Other	0.78 (0.67 to 0.91)	<.001	0.76 (0.62 to 0.91)	.004
Admitted to ICU during hospitalization	1.01 (0.94 to 1.09)	.91	0.95 (0.86 to 1.03)	.23
LOS	1.01 (1.00 to 1.02)	.01	1.01 (1.00 to 1.02)	.04
Anti-*Pseudomonas* antibiotic on hospital day 0–1	0.91 (0.85 to 0.97)	<.001	0.94 (0.86 to 1.02)	.12
Hospital region				
West	Ref	—	Ref	—
Midwest	1.24 (1.01 to 1.62)	.04	1.28 (1.03 to 1.60)	.03
Northeast	1.09 (0.90 to 1.38)	.43	1.15 (0.90 to 1.46)	.26
South	1.01 (0.84 to 1.24)	.96	1.05 (0.87 to 1.31)	.65
Hospital-level empirical anti-*Pseudomonas* antibiotic	1.07 (0.69 to 1.60)	.72	0.92 (0.63 to 1.41)	.67
No. cases, unit change per 100	1.01 (0.99 to 1.03)	.65	1.00 (0.98 to 1.03)	.72
Census, unit change per 100	1.02 (0.94 to 1.11)	.63	0.99 (0.90 to 1.08)	.87

—, not applicable.

associated with both longer LOS and increased odds for 30-day revisit. Other variables (eg, public insurance, ICU admission, acute mechanical ventilation, and patient-level empirical anti-*Pseudomonas* antibiotics) were associated with longer LOS but not with increased revisit odds. Specific factors not associated with LOS or revisit included patient race, size of the hospital, number of cases, and hospital-level use of empirical anti-*Pseudomonas* antibiotics

The median LOS of 4 days seen in our study is higher than both the 2-day LOS seen in patients without CCCs hospitalized with community-acquired pneumonia[10,14,17] and the 3-day LOS seen in patients with CCCs hospitalized with community-acquired

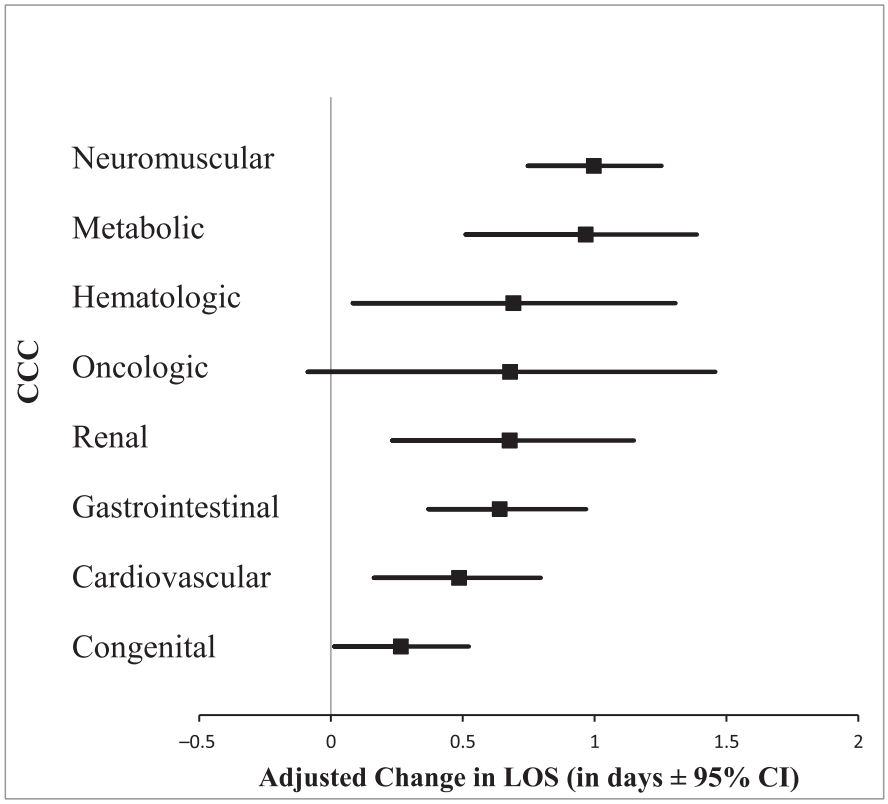

FIGURE 1 Association between individual CCCs and LOS. LOS is adjusted for all variables in Table 2, except for the total number of CCCs.

pneumonia.[10] The LOS nadir seen at ages of 1 to 4 years may reveal different indications for tracheostomy placement, lower physiologic reserves, or a lower threshold for hospitalization in children <12 months, although older patients may have more morbidity from their chronic medical problems. The 30-day overall hospital revisit rate of 30.5% and the 30-day readmission rate of 22.9% in this cohort is markedly higher than the 1% to 7% 30-day hospital readmission rates seen for cases of community-acquired pneumonia in children both with and without CCCs.[10,11] The inverse relationship seen between higher admission age and lower readmission odds may be caused by increasing parental knowledge and comfort gained through managing their children throughout years. Not surprisingly, patients with 4 or more CCCs had significantly longer LOS and higher odds of readmission, after controlling for other variables. Similarly, patients with chronic ventilator dependency represent another population with high medical complexity[18–21] and, therefore, are at a high risk for readmission and health care use.[22] Overall, our findings are consistent with those from previous studies, which revealed longer LOS and higher revisit rates in publicly insured and medically complex patients admitted with community-acquired pneumonia[10,11,14,23] and aspiration pneumonia.[24]

We found an association between patient receipt of empirical *P aeruginosa* antibiotics and increased LOS. The authors of recent work have demonstrated that *P aeruginosa* is a common respiratory isolate in pediatric patients admitted with aspiration pneumonia[25,26] and in pediatric patients after tracheotomy.[27,28] This result complements recent work revealing an association between *P aeruginosa* isolation and poorer outcomes, including readmission for a bTARTI,[28] ICU admission, and intubation.[26] Receiving antibiotics targeting *P aeruginosa* may be a proxy for higher illness severity or increased likelihood of having multidrug-resistant organisms. Given the limited enteral alternatives for *P aeruginosa* treatment, patients may require longer hospitalization for intravenous antibiotics. With our current findings, we add to the literature produced to highlight the need for additional research on interventions in the prevention and treatment of respiratory infections caused by multidrug-resistant organisms and on the increased roles of antimicrobial stewardship programs to limit the unnecessary use of broad-spectrum antibiotics.

The associations among principal diagnoses, LOS, and revisit odds should be further explored. We found a shorter LOS without increased revisit rates in patients diagnosed with bacterial tracheitis. Patients diagnosed with bacterial tracheitis may have a shorter LOS because this condition may not be associated with the hypoxemia seen in pneumonia and because antibiotic courses for the condition may be shorter.[29] Similarly, those with a primary diagnosis of a symptom of bacterial illness or viral infection may have a LOS because of delays in diagnosis or because these patients began with a viral infection and subsequently developed a bacterial superinfection that required treatment. However, the longer LOS in this group was balanced with statistically lower odds of readmission.

The current study had the limitations associated with conducting an observational, retrospective study by using administrative data, which included being able to demonstrate associations without being able to make a causal link. We could only study patients hospitalized at participating PHIS hospitals; there are missing children hospitalized for bTARTIs at non-PHIS–contributing children's hospitals or at community hospitals not included in PHIS. In addition, we could not track readmission to a non-PHIS hospital; therefore, we may not have captured all patient revisits. With the use of administrative data, we relied on accurate coding and translation of existing data; by using our inclusion criteria, we may have missed patients who were hospitalized for a

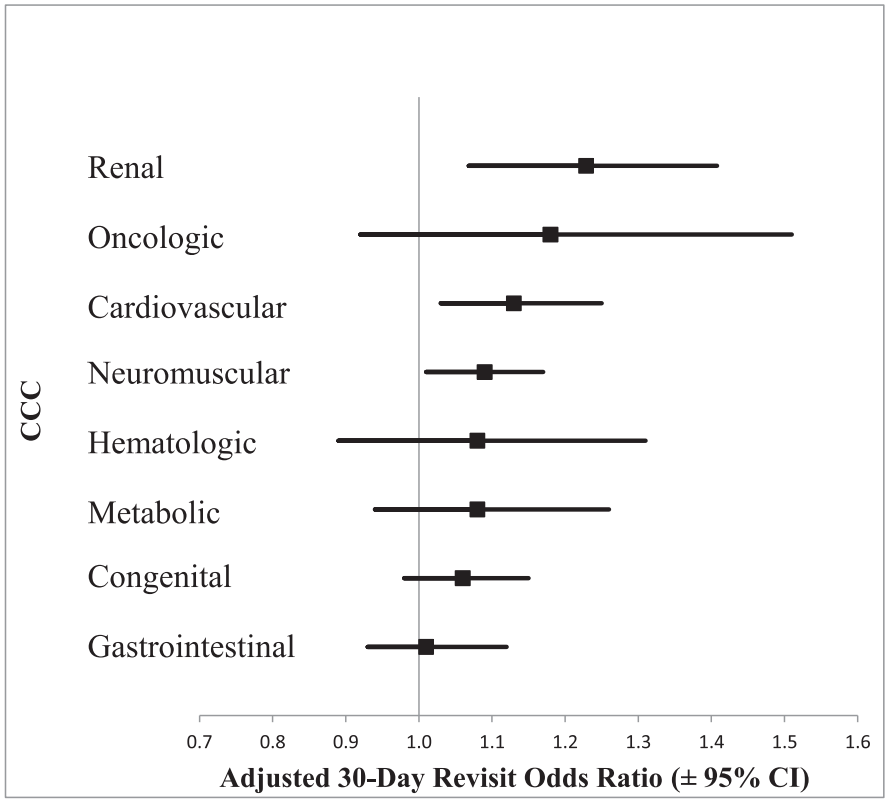

FIGURE 2 Association between individual CCCs and 30-day all-cause hospital revisits. Thirty-day all-cause hospital revisit rates are adjusted for all variables in Table 3, except for the total number of CCCs.

bTARTI but whose discharges were not assigned the representative ICD-9-CM codes, or we may have included patients incorrectly coded as having a bTARTI. Additionally, we did not include patients with a primary diagnosis associated with respiratory failure and a secondary diagnosis of a respiratory infection, which limits generalizability for patients who may have a higher illness severity. Because we used an administrative database, we were unable to obtain actual test results (eg, respiratory cultures, Gram-stain results) that could have been used as objective information to differentiate between acute infection and chronic colonization in those cases assigned ICD-9-CM codes for bacterial infection. Thus, there may have been an overdiagnosis of bacterial respiratory infections in this population, which may have led to increased health care use and costs. This may also have led to an overestimation of the total burden of bTARTIs in pediatric patients when using administrative data. Finally, given the retrospective nature of the study, there may have been unmeasured confounders that led to the observations noted.

Notwithstanding these limitations, this is the first study in which the authors identify specific factors associated with longer LOS and increased odds for 30-day hospital revisit in pediatric patients admitted with bTARTIs. We have found that patients <12 months old with ≥ 4 CCCs and chronic ventilator dependency are at the highest risk for longer LOS and for hospital revisit. Providers can use this information when counseling families about possible adverse outcomes after tracheotomy. Given the identified factors, the authors of future studies should (1) identify a patient population that may benefit from bTARTI prevention strategies (eg, prophylactic or suppressive inhaled antibiotic therapy for *Pseudomonas* colonization); (2) develop evidence-based guidelines for diagnosis and management of children with bTARTIs, including differentiation between acute infection and chronic colonization; and (3) develop interventions for specific populations (eg, younger patients, patients requiring chronic mechanical ventilation, and patients with neuromuscular, cardiovascular, or renal comorbidities) to minimize longer LOS and revisit risk.

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