Vaccination Status and Resource Use During Hospital Visits for Respiratory Illnesses

Mersine A. Bryan, MD, MPH,[a,b] Annika M. Hofstetter, MD, PhD, MPH,[a,b] M. Patricia deHart, ScD,[c] Tamara D. Simon, MD, MSPH,[a,b] Douglas J. Opel, MD, MPH[a,b]

abstract

OBJECTIVES: To evaluate variation in resource use for children with acute respiratory tract illness (ARTI) by vaccination status.

METHODS: We conducted a retrospective cohort study of children 0 to 16 years of age at 5 children's hospitals with 1 of 4 ARTI diagnoses (pneumonia, croup, asthma, and bronchiolitis) between July 2014 and June 2016. The predictor variable was provider-documented up-to-date (UTD) vaccination status (yes or no). Outcomes were receipt of each of the following tests or treatments (yes or no): complete blood cell count, blood cultures, C-reactive protein (CRP) level testing, viral testing, influenza testing, pertussis testing, chest radiographs, neck radiographs, antibiotics, and corticosteroids. We generated multivariable logistic regression models to examine the associations between our predictor and outcomes.

RESULTS: Of the 2302 participants included in analysis, 568 (25%) were diagnosed with pneumonia, 343 (15%) were diagnosed with croup, 653 (28%) were diagnosed with asthma, and 738 (32%) were diagnosed with bronchiolitis. Most (92%) vaccination statuses were documented as UTD. Across conditions, children whose vaccination status was documented as not UTD had higher adjusted odds of receiving a complete blood cell count, blood culture, CRP level testing, and influenza testing ($P < .001$). Children with pneumonia whose vaccination status was documented as not UTD had higher adjusted odds of receiving CRP level testing and influenza testing ($P < .001$). Children with croup whose vaccination status was documented as not UTD had higher adjusted odds of receiving blood cultures ($P < .001$).

CONCLUSIONS: Children with ARTI whose vaccination status was documented as not UTD had higher odds of undergoing laboratory testing compared with children whose vaccination status was documented as UTD.

[a]*Department of Pediatrics, School of Medicine, University of Washington, Seattle, Washington;* [b]*Seattle Children's Research Institute, Seattle, Washington; and* [c]*Washington State Department of Health, Tumwater, Washington*

Dr Bryan conceptualized the study design, conducted the data analysis, and wrote the first draft of the manuscript; Drs Hofstetter, deHart, Simon, and Opel contributed to the study design and interpretation of study data and critically reviewed the manuscript to provide key intellectual content; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

DOI: https://doi.org/10.1542/peds.2019-0585

Accepted for publication Aug 21, 2019

Address correspondence to Mersine A. Bryan, MD, MPH, Department of Pediatrics, School of Medicine, University of Washington, Mail Stop CW8-5b, PO Box 5371, Seattle, WA 98145. E-mail: mersine@uw.edu

WHAT'S KNOWN ON THIS SUBJECT: Children who are undervaccinated are at risk of vaccine-preventable diseases, including acute respiratory tract illnesses. Additionally, they have higher rates of emergency department visits and inpatient hospitalizations compared with children who are fully vaccinated.

WHAT THIS STUDY ADDS: There is variation in care for children who are undervaccinated compared with children who are fully vaccinated. Children who are undervaccinated and receive hospital-based care for acute respiratory tract illnesses undergo more laboratory testing than children who are fully vaccinated.

To cite: Bryan MA, Hofstetter AM, deHart MP, et al. Vaccination Status and Resource Use During Hospital Visits for Respiratory Illnesses. *Pediatrics.* 2019;144(5):e20190585

Acute respiratory tract illnesses (ARTIs) account for significant morbidity in children and are a main cause of pediatric emergency department (ED) visits and hospitalizations annually.[1–6] Despite their high frequency, significant variation in the care of children with ARTIs has been observed.[7–11] The reason for this variation remains incompletely understood.

One potential explanation for this variability in the care of children with ARTIs is a child's vaccination status. Children who are undervaccinated for vaccine-preventable ARTIs, such as pneumonia, influenza, and pertussis, are at a higher risk of developing these ARTIs.[12–14] In addition, children who are undervaccinated have higher all-cause hospital admissions and more frequent ED visits.[15–17] Because of their higher risk and/or more frequent use of health care in hospital-based care settings, providers may conduct more testing and treatment of undervaccinated children presenting with ARTIs.

Our primary objective for this study was to evaluate variation in ED and inpatient resource use for children with ARTI by vaccination status. We hypothesized that undervaccinated children presenting to the ED or hospital with ARTI would receive more laboratory and radiographic testing and medication treatment.

METHODS

Study Population

We conducted a retrospective cohort study of children who presented with ARTI between July 2014 and June 2016 to 5 freestanding academic children's hospitals participating in the Pediatric Research in Inpatient Settings network. ARTI was defined as community-acquired pneumonia (CAP), croup, asthma, and bronchiolitis. Children were included in the study if they were between 2 weeks and 16 years old, if the family spoke English or Spanish, and if they had 1 of the 4 aforementioned ARTI conditions. We focused on ARTI because (1) ARTI is a common cause of pediatric hospital admission and (2) a child's vaccination status is relevant to the diagnosis of ARTI because many vaccine-preventable diseases (VPDs), such as influenza, pertussis, and pneumococcal disease, are in the differential diagnosis. Subjects were excluded if they (1) had an underlying condition that would alter the routine childhood vaccination schedule (including requiring additional vaccines), such as immune deficiencies, HIV, or asplenia, per the recommendations of the Advisory Committee on Immunization Practices[18] or (2) had a chronic medical condition that would alter the standard of care for ARTI, including history of cardiac disease, anatomic airway abnormalities, cystic fibrosis, neuromuscular disease, bronchopulmonary dysplasia, or chronic lung disease. All children in the study who were diagnosed with CAP, asthma, and bronchiolitis were admitted to the hospital. Children with croup were either seen in the ED and admitted or seen in the ED and discharged. We opted to include children with croup who were discharged from the ED given the lower rates of admission for croup. If a child had multiple hospitalizations during the study period, only the first hospitalization was included in this analysis. This study was approved by the Western Institutional Review Board.

Variables

The primary predictor variable was provider-documented up-to-date (UTD) vaccination status (yes or no) at the time of hospital presentation. This variable was abstracted from the electronic medical record (EMR) from either the ED or admission note. Previous studies have revealed that provider-documented UTD status may not be reflective of true vaccination status.[19–21] However, we selected it as our predictor variable because it represented the information that providers had at the point of care when making clinical decisions during the hospital visit. Subjects were excluded if there was no provider documentation of vaccination status in the EMR. Of note, all hospitals in the study had a specific vaccination question included in their EMR note templates for ED notes and admission history and physical notes. At the time of this study, none of the 5 hospitals received vaccination data from local population-based immunization information systems (IISs). Thus, provider-documented UTD status was the only vaccination data included in the EMR.

The outcome variables of interest were receipt of laboratory tests, radiographic studies, and medication treatment of ARTI. We used the Pediatric Health Information System (PHIS) database to obtain outcome data. PHIS is a de-identified administrative database that contains information on diagnoses, laboratory investigations, radiographic studies, and medications for 47 children's hospitals across the United States. For each participant, we examined the PHIS to identify laboratory tests, radiographic studies, and medications they received during the current hospitalization. We a priori selected laboratory tests, radiographic studies, and medications that were clinically relevant to ARTI: complete blood cell (CBC) count, blood culture, C-reactive protein (CRP) level testing, respiratory viral testing, influenza testing, pertussis testing, chest radiographs, neck radiographs, antibiotic use, and corticosteroid use. Clinical relevance was determined from clinical practice guidelines, a literature review, and consensus among study authors.[7,11,22–24] For respiratory viral testing, we included testing for any of the following respiratory viruses: adenovirus,

metapneumovirus, respiratory syncytial virus, rhinovirus, parainfluenza, and influenza. We also included nonspecific viral tests, such as viral cultures and unspecified viral polymerase chain reaction tests, and nucleic acid amplification tests. We examined influenza and pertussis tests as separate variables because both of these tests were specifically related to VPDs.

We queried the PHIS for at least 1 occurrence (yes or no) of each of the aforementioned tests and treatments during the included visit. We examined the mean number of diagnostic laboratory tests and radiographic studies each participant received during hospitalization (range 0–8) as well as the number and type of antibiotics each participant received. Antibiotics were classified by type (ie, penicillin, cephalosporins, macrolides, etc) and categorized into 2 groups: narrow and broad spectrum. Narrow-spectrum antibiotics included penicillin and macrolides or a combination of penicillin and macrolide. Broad-spectrum antibiotics included cephalosporins, fluoroquinolones, aminoglycosides, antistaphylococcal antibiotics (such as vancomycin), or a combination therapy that included at least 1 of these agents.[25,26]

Covariates of interest included child age at presentation, sex, race and/or ethnicity, insurance, chronic disease status, admission to the ICU, and month of presentation. We categorized age into 4 groups (0–18 months, 19–35 months, 3–6 years, and >6 years) to correspond to the age categories typically used in population-level evaluations of vaccination coverage,[27] although participants >6 years were aggregated because of small sample size. Chronic disease status was determined by using the Pediatric Medical Complexity Algorithm (PMCA).[28] A chart review was performed for all subjects with complex chronic disease to ensure they met study eligibility criteria. The month of presentation was included to account for seasonal trends and categorized into influenza season (October–March) and noninfluenza season (April–September).[29]

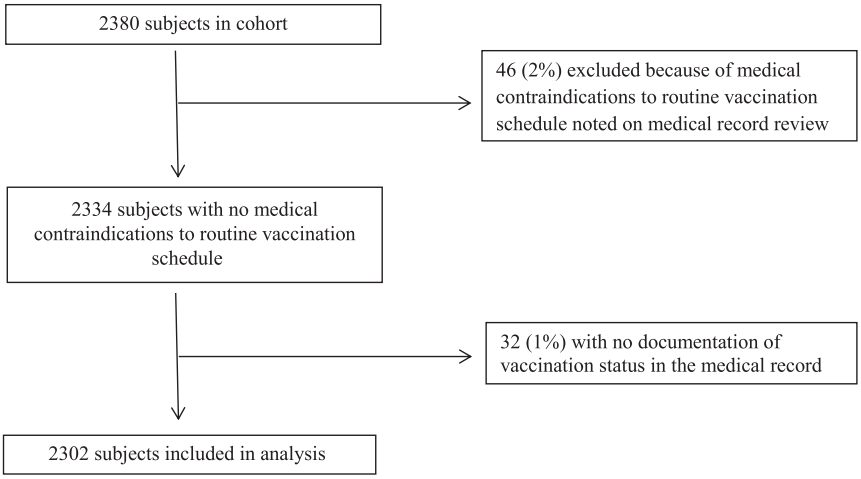

FIGURE 1
Study population.

Statistical Analysis

Univariate descriptive statistics were used to examine the cohort of subjects. We used χ^2 tests and bivariate logistic regression to assess the relationship between (1) covariates and the predictor variable, (2) covariates and the outcome variables, and (3) our predictor and outcome variables. To test the independent associations between the predictor and outcome variables, we used multivariable logistic regression models that included covariates with a significant ($P < .05$) relationship with the predictor variable and outcome variables. We additionally adjusted models for length of stay (LOS) in days as a continuous variable to account for time in the hospital as a possible confounder for receiving more testing. Because variability in practice for these conditions could influence site-specific care, we included hospital site as a fixed effects variable, with clustering of SEs by site.

We generated multivariable generalized linear regression models to examine the relationship between the number of diagnostic tests received (0–8) by each individual by UTD status. We generated multivariable logistic regression models to examine binary use of each test and treatment. We examined models for the entire cohort of subjects as well as models for each of the 4 respiratory conditions. To account for multiple comparisons, we used a Bonferroni-corrected critical $P = .006$.

Sensitivity Analysis

None of the hospitals in our study had IIS data integrated in their EMR. Because of time and budget constraints, we were unable to obtain individual-level vaccine records for all participants, but we were able to obtain IIS vaccination data for the subjects included in the study from 1 study site. For this subset of subjects, we conducted a sensitivity analysis to compare IIS UTD status against resource use. Children's vaccination status was considered UTD if the child had received all age-appropriate vaccine doses, including for influenza,

TABLE 1 Demographic Variables by Provider-Documented Vaccination Status

	All Participants (N = 2302), n (%)	UTD (n = 2123), n (%)	Not UTD (n = 179), n (%)	Unadjusted Odds Ratio (95% CI)	P
Age					.34
≤18 mo	1028 (45)	943 (44)	85 (47)	Reference	
19–35 mo	348 (15)	320 (15)	28 (16)	1.0 (0.7–1.6)	
3–6 y	534 (23)	490 (23)	44 (25)	1.0 (0.7–1.5)	
≥7 y	392 (17)	370 (17)	22 (12)	1.5 (0.9–2.5)	
Sex					.43
Male	1364 (59)	1253 (59)	111 (62)	0.9 (0.6–1.2)	
Race and/or ethnicity					.03
White	910 (40)	836 (39)	74 (34)	Reference	
African American	512 (22)	485 (23)	27 (15)	1.6 (1.0–2.5)	
Hispanic	556 (24)	500 (24)	56 (31)	0.8 (0.5–1.1)	
Other	307 (13)	285 (13)	22 (12)	1.1 (0.7–1.9)	
Missing	17 (1)	17 (1)	0 (0)	—	
Insurance					.67
Private	999 (43)	924 (44)	75 (42)	Reference	
Public	1303 (57)	1199 (56)	104 (58)	0.7 (0.7–1.3)	
PMCA					.03
Nonchronic	1278 (56)	1162 (55)	116 (65)	Reference	
Noncomplex chronic	920 (40)	865 (41)	55 (31)	1.6 (1.1–2.2)	
Complex chronic	101 (4)	93 (4)	8 (4)	1.2 (0.5–2.4)	
Missing	3 (0)	3 (0)	0 (0)	—	
ICU admission	145 (6)	130 (6)	15 (8)	0.7 (0.4–1.2)	.24
Seasonality					.002
April to September	806 (35)	762 (36)	44 (25)	Reference	
October to March	1496 (65)	1361 (64)	135 (75)	0.6 (0.4–0.8)	
Hospital					<.001
1	528 (23)	513 (24)	15 (8)	Reference	
2	488 (21)	403 (19)	85 (47)	0.1 (0.1–0.2)	
3	468 (20)	431 (20)	37 (21)	0.3 (0.2–0.6)	
4	278 (12)	250 (12)	28 (16)	0.3 (0.1–0.5)	
5	540 (23)	526 (25)	14 (8)	1.1 (0.5–2.3)	
Diagnosis					.002
CAP	568 (25)	504 (24)	64 (36)	Reference	
Croup	343 (15)	314 (15)	29 (16)	1.4 (0.9–2.2)	
Asthma	653 (28)	617 (29)	36 (20)	2.2 (1.4–3.3)	
Bronchiolitis	738 (32)	688 (32)	50 (28)	1.7 (1.2–2.6)	

—, unable to calculate odds ratio because n = 0

per the Advisory Committee on Immunization Practices guidelines. We generated multivariable logistic regression models to examine binary use of each test and treatment by IIS UTD status. We examined models of the entire cohort of subjects as well as each of the 4 respiratory conditions. All models were adjusted for race and/or ethnicity, PMCA, season of presentation, and LOS.

RESULTS

Of 2380 children identified with ARTI, 46 (2%) were excluded because of underlying conditions identified by an EMR review, and 32 (1%) had no documentation of vaccine status in their EMR (Fig 1). Of the remaining 2302 participants included in analysis, the mean age was 3.5 years (SD 3.7), and 59% were boys (Table 1). There were 568 (25%) participants who presented with CAP, 343 (15%) who presented with croup, 653 (28%) who presented with asthma, and 738 (32%) who presented with bronchiolitis. Most (92%) had an UTD vaccination status by provider documentation. Race and/or ethnicity, PMCA, season of presentation, site, and diagnosis were all significantly related to provider-documented UTD status.

The mean number of diagnostic tests received was 1.4 (SD 1.5; range 0–7). There was a significantly higher mean number of diagnostic tests ordered for children whose vaccination status was documented as not UTD compared with those whose vaccination status was UTD (unadjusted: not UTD: 1.9 [95% confidence interval (CI) 1.6–2.1] versus UTD: 1.3 [95% CI 1.3–1.4]; $P < .001$; adjusted: not UTD: 0.8 [95% CI 0.5–1.0] versus UTD: 0.4 [95% CI 0.2–0.5]; $P = .005$).

When evaluating each test or treatment individually, children whose vaccination status was

TABLE 2 Relationship of UTD Vaccination Status With Laboratory Testing for Children With ARTI

Outcome	Vaccine Status	*n* (%) Received	Unadjusted Odds Ratio (95%CI)	*P*	aOR (95%CI)	*P*[a]
All conditions						
CBC count	UTD	400 (19)	Reference	.02	Reference	<.001
	Not UTD	47 (26)	1.5 (1.1–2.2)		1.7 (1.3–2.2)	
Blood culture	UTD	337 (16)	Reference	.07	Reference	<.001
	Not UTD	38 (21)	1.4 (1.0–2.1)		1.7 (1.5–1.9)	
CRP	UTD	110 (5)	Reference	<.001	Reference	<.001
	Not UTD	22 (12)	2.6 (1.6–4.2)		3.1 (2.7–3.5)	
Respiratory viral testing	UTD	682 (32)	Reference	.001	Reference	.39
	Not UTD	79 (44)	1.7 (1.2–2.3)		1.2 (0.8–1.8)	
Influenza-specific testing	UTD	193 (9)	Reference	.36	Reference	.001
	Not UTD	20 (11)	1.3 (0.8–2.0)		1.6 (1.2–2.1)	
Pertussis-specific testing	UTD	140 (7)	Reference	<.001	Reference	.80
	Not UTD	26 (15)	2.4 (1.5–3.8)		1.1 (0.5–2.2)	
CAP						
CBC count	UTD	265 (53)	Reference	.53	Reference	.12
	Not UTD	31 (48)	0.8 (0.5–1.4)		1.2 (0.9–1.6)	
Blood culture	UTD	208 (41)	Reference	.56	Reference	.22
	Not UTD	24 (38)	0.8 (0.5–1.5)		1.2 (0.9–1.7)	
CRP	UTD	80 (16)	Reference	.002	Reference	.001
	Not UTD	20 (31)	2.4 (1.3–4.3)		2.9 (1.6–5.4)	
Respiratory viral testing	UTD	202 (40)	Reference	.13	Reference	.78
	Not UTD	32 (50)	1.5 (0.9–2.5)		1.1 (0.6–1.9)	
Influenza-specific testing	UTD	67 (13)	Reference	.87	Reference	.001
	Not UTD	9 (14)	1.1 (0.5–2.2)		1.8 (1.3–2.5)	
Pertussis-specific testing	UTD	54 (11)	Reference	.002	Reference	.69
	Not UTD	16 (25)	2.8 (1.5–5.2)		1.2 (0.5–2.6)	
Croup						
CBC count	UTD	20 (6)	Reference	.04	Reference	.68
	Not UTD	5 (17)	3.1 (1.1–8.9)		1.3 (0.4–4.1)	
Blood culture	UTD	6 (2)	Reference	.11	Reference	<.001
	Not UTD	2 (7)	3.8 (0.7–19.8)		3.0 (2.2–4.0)	
CRP	UTD	6 (2)	Reference	.58	Reference	.24
	Not UTD	1 (3)	1.8 (0.2–15.8)		1.4 (0.8–2.4)	
Respiratory viral testing	UTD	44 (14)	Reference	<.001	Reference	.23
	Not UTD	12 (41)	4.3 (1.9–9.7)		2.3 (0.6–9.0)	
Influenza-specific testing	UTD	9 (3)	Reference	.86	Reference	.99
	Not UTD	1 (3)	1.2 (0.1–9.9)		1.0 (0.1–31.9)	
Pertussis-specific testing	UTD	12 (4)	Reference	.004	Reference	.08
	Not UTD	5 (17)	5.2 (1.7–16.1)		2.1 (0.9–4.9)	
Asthma						
CBC count	UTD	28 (5)	Reference	.34	Reference	.07
	Not UTD	3 (8)	1.9 (0.6–6.6)		2.6 (0.9–7.1)	
Blood culture	UTD	12 (2)	Reference	.73	Reference	.27
	Not UTD	1 (3)	1.4 (0.2–11.4)		3.1 (0.4–22.7)	
CRP	UTD	7 (1)	Reference	.52	Reference	.86
	Not UTD	0 (0)	—		—	
Respiratory viral testing	UTD	136 (22)	Reference	.71	Reference	.001
	Not UTD	7 (19)	0.9 (0.4–2.0)		0.5 (0.4–0.8)	
Influenza-specific testing	UTD	18 (3)	Reference	.96	Reference	.65
	Not UTD	1 (3)	1.0 (0.1–7.3)		1.8 (0.1–24.3)	
Pertussis-specific testing	UTD	18 (3)	Reference	.96	Reference	.01
	Not UTD	1 (3)	1.0 (0.1–7.3)		0.3 (0.1–0.8)	
Bronchiolitis						
CBC count	UTD	87 (13)	Reference	.51	Reference	.61
	Not UTD	8 (16)	1.3 (0.6–2.9)		1.4 (0.3–6.0)	
Blood culture	UTD	111 (16)	Reference	.28	Reference	.20
	Not UTD	11 (22)	1.5 (0.7–3.0)		1.8 (0.7–4.3)	
CRP	UTD	17 (2)	Reference	.84	Reference	.77
	Not UTD	1 (2)	0.8 (0.1–6.2)		1.4 (0.1–16.0)	

TABLE 2 Continued

Outcome	Vaccine Status	*n* (%) Received	Unadjusted Odds Ratio (95%CI)	*P*	aOR (95%CI)	*P*[a]
Respiratory viral testing	UTD	300 (44)	Reference	.09	Reference	.30
	Not UTD	28 (56)	1.6 (0.9–2.9)		1.7 (0.6–4.8)	
Influenza-specific testing	UTD	99 (14)	Reference	.49	Reference	.04
	Not UTD	9 (18)	1.3 (0.6–2.8)		1.7 (1.0–2.9)	
Pertussis-specific testing	UTD	56 (8)	Reference	.97	Reference	.48
	Not UTD	4 (8)	1.0 (0.3–2.8)		0.6 (0.1–2.6)	

This relationship was evaluated by using logistic regression adjusted for race and/or ethnicity, level of medical complexity, season of admission, LOS, and hospital site. —, unable to calculate odds ratio because $n = 0$.

[a] Bonferroni-corrected critical $P < .006$.

documented as not UTD (versus UTD) had higher odds of receiving laboratory testing (Table 2). In analyses across all 4 conditions adjusted for race and/or ethnicity, PMCA, season of presentation, site, and LOS, children whose vaccination status was documented as not UTD (versus UTD) had higher odds of receiving a CBC count (adjusted odds ratio [aOR] 1.7; 95% CI 1.3–2.2; $P < .001$), blood culture (aOR 1.7; 95% CI 1.5–1.9; $P < .001$), CRP level testing (aOR 3.1; 95% CI 2.7–3.5; $P < .001$), and influenza-specific testing (aOR 1.6; 95% CI 1.2–2.1; $P = .001$). There were not significantly higher odds of receiving radiographic tests or medications for children whose vaccination status was not UTD compared with those whose vaccination status was UTD (Table 3).

In adjusted condition-specific models, children with CAP and croup whose vaccination status was documented as not UTD (versus UTD) had higher odds of receiving some laboratory tests (CAP: CRP level testing and influenza testing; croup: blood culture) (Table 2). For asthma, there were lower odds of receiving nonspecific viral testing and antibiotics for children without documented UTD vaccination status compared with those with documented UTD vaccination status (Tables 2 and 3). There were no differences in resource use by vaccination status for children with bronchiolitis (Tables 2 and 3). There was also no significant difference in adjusted odds of receipt of narrow- or broad-spectrum antibiotics by vaccination status for subjects with all conditions and those with CAP (Table 4).

Sensitivity Analysis

In the sensitivity analysis used to examine the relationship between binary use of each test and treatment of children whose vaccination status was UTD by IIS records for 1 site, we identified no significant differences in the adjusted odds of receiving any laboratory tests, radiographic studies, or medications by vaccination status (Supplemental Table 5).

DISCUSSION

In a large multisite retrospective cohort of children with ARTI, we examined variation in resource use by provider-documented child vaccination status at hospital presentation. Overall, we identified that children with ARTI whose vaccination status was documented as not UTD had higher odds of undergoing diagnostic testing compared with children whose vaccination status was documented as UTD. In particular, we found higher odds of testing for children with CAP and croup whose vaccination status was documented as not UTD compared with children with the same conditions whose vaccination status was documented as UTD.

It is noteworthy that many of the tests in which we identified differences by vaccination status are nonspecific, such as CBC counts and CRP level tests, and it is unknown how the results influence subsequent medical decision-making for children admitted with ARTI. In previous work, Glanz et al[16] identified higher rates of ED visits and inpatient admissions for children who were undervaccinated compared with those who were fully vaccinated, suggesting there are differences in how children who are undervaccinated seek care for acute illnesses. Our results suggest that when children with ARTI seek care in hospital settings and are documented as not having an UTD vaccination status, they experience higher resource use of nonspecific diagnostic testing.

The routine childhood vaccination schedule includes vaccines against *Bordetella pertussis*, *Haemophilus influenzae* type b, *Streptococcus pneumoniae*, and influenza, all of which can be pathogens in ARTI.[30] Because the differential diagnoses for ARTI can include these pathogens, the medical decision-making of a provider treating a child with ARTI whose vaccination status is not UTD may be different from the medical decision-making of a provider when the child's vaccination status is considered to be

TABLE 3 Relationship of UTD Vaccination Status With Use of Radiographic Studies and Medications for Children With ARTI

Outcome	Vaccine Status	*n* (%) Received	Unadjusted Odds Ratio (95%CI)	*P*	aOR (95%CI)	*P*[a]
All conditions						
Chest radiograph	UTD	900 (42)	Reference	.01	Reference	.04
	Not UTD	93 (52)	1.5 (1.1–2.0)		1.4 (1.0–2.1)	
Neck radiograph	UTD	80(4)	Reference	.25	Reference	.41
	Not UTD	10 (6)	1.5 (0.8–3.0)		1.4 (0.7–2.8)	
Corticosteroids	UTD	1091 (51)	Reference	.01	Reference	.08
	Not UTD	75 (42)	0.7 (0.5–0.9)		0.7 (0.5–1.0)	
Antibiotics	UTD	709 (33)	Reference	.002	Reference	.09
	Not UTD	80 (45)	1.6 (1.2–2.2)		1.5 (0.9–2.3)	
CAP						
Chest radiograph	UTD	398 (79)	Reference	.88	Reference	.14
	Not UTD	50 (78)	1.0 (0.5–1.8)		0.7 (0.4–1.1)	
Neck radiograph	UTD	3 (1)	Reference	.40	Reference	.07
	Not UTD	1 (2)	2.7 (0.3–25.9)		5.0 (0.9–29.2)	
Corticosteroids	UTD	132 (6)	Reference	.07	Reference	.01
	Not UTD	10 (16)	0.5 (0.3–1.1)		0.4 (0.2–0.8)	
Antibiotics	UTD	475 (94)	Reference	.05	Reference	—
	Not UTD	64 (100)	—		—	
Croup						
Chest radiograph	UTD	53 (17)	Reference	.16	Reference	.23
	Not UTD	8 (28)	1.9 (0.8–4.5)		1.6 (0.8–3.2)	
Neck radiograph	UTD	73 (23)	Reference	.60	Reference	.92
	Not UTD	8 (28)	1.3 (0.5–3.0)		1.1 (0.4–2.7)	
Corticosteroids	UTD	260 (83)	Reference	.35	Reference	.09
	Not UTD	22 (76)	0.7 (0.3–1.6)		0.5 (0.2–1.1)	
Antibiotics	UTD	25 (8)	Reference	.10	Reference	.28
	Not UTD	5 (17)	2.4 (0.8–6.8)		1.8 (0.6–4.9)	
Asthma						
Chest radiograph	UTD	201 (33)	Reference	.43	Reference	.58
	Not UTD	14 (39)	1.3 (0.7–2.6)		1.2 (0.6–2.7)	
Neck radiograph	UTD	1 (0)	Reference	.04	Reference	.38
	Not UTD	1 (3)	17.6 (1.1–287.3)		20.3 (0.1–1766)	
Corticosteroids	UTD	599 (97)	Reference	.96	Reference	.35
	Not UTD	35 (97)	1.1 (0.1–8.1)		0.5 (0.1–2.1)	
Antibiotics	UTD	63 (10)	Reference	.37	Reference	<.001
	Not UTD	2 (6)	0.5 (0.1–2.2)		0.3 (0.2–0.5)	
Bronchiolitis						
Chest radiograph	UTD	248 (36)	Reference	.41	Reference	.36
	Not UTD	21 (42)	1.3 (0.7–2.3)		1.4 (0.7–2.9)	
Neck radiograph	UTD	3 (0)	Reference	.73	Reference	—
	Not UTD	0 (0)	—		—	
Corticosteroids	UTD	100 (15)	Reference	.78	Reference	.67
	Not UTD	8 (16)	1.1 (0.5–2.5)		0.9 (0.5–1.6)	
Antibiotics	UTD	146 (21)	Reference	.59	Reference	.32
	Not UTD	9 (18)	0.8 (0.4–1.7)		0.7 (0.4–1.4)	

This relationship was evaluated by using logistic regression adjusted for race and/or ethnicity, level of medical complexity, season of admission, LOS, and hospital site. —, not applicable.
[a] Bonferroni-corrected critical $P < .006$.

UTD. Our finding that differences in resource use by vaccination status were predominantly related to testing versus treatment reveals that providers may experience more diagnostic uncertainty in children with ARTI whose vaccination status is not UTD. This uncertainty may lead to more nonspecific testing to help rule out, for example, serious bacterial illness. However, if diagnostic uncertainty existed in a child whose vaccination status was not UTD, specific testing for certain VPDs would be most appropriate. With the exception of influenza testing, we did not observe any differences in testing for specific VPDs by vaccination status. Secondly, this observed increase in nonspecific testing did not appear to result in increased odds of receiving treatment. For example, we identified no difference in the use of broad-spectrum antibiotics in children with CAP who were undervaccinated.

TABLE 4 Relationship Between UTD Vaccination Status and Antibiotic Use for Children With ARTIs

Type of Antibiotic	UTD, *n* (%)	Not UTD, *n* (%)	Odds Ratio (95% CI)	*P*	aOR (95%CI)	*P*[a]
All conditions						
None	1420 (67)	99 (55)	Reference	.008	Reference	.38
Narrow	428 (20)	51 (28)	1.6 (1.1–2.2)		1.3 (0.7–2.5)	
Broad	282 (13)	29 (16)	1.3 (0.8–1.9)		1.3 (0.7–2.3)	
CAP						
None	29 (6)	0 (0)	Reference	.12	Reference	.50
Narrow	278 (55)	40 (63)	1.4 (0.8–2.3)		1.1 (0.4–2.6)	
Broad	198 (39)	38 (24)	0.9 (0.5–1.6)		1.0 (0.4–2.7)	

This relationship was evaluated by using logistic regression models adjusted for race and/or ethnicity, level of medical complexity, season of admission, LOS, and site.
[a] Bonferroni-corrected critical $P < .006$.

Therefore, an important takeaway from our results is for hospital-based physicians to consider whether nonspecific testing contributes to their management of children who they have identified as undervaccinated.

There have been substantial quality improvement efforts to decrease nonspecific diagnostic tests, particularly for ARTI.[31–36] Our study results reveal that vaccination status is an important variable to consider when implementing these efforts. For instance, improving vaccination rates within a population may be an important component to efforts to help hospital-based providers be more parsimonious with nonspecific diagnostic testing. Understanding medical decision-making by providers in hospital settings regarding the testing and treatment of undervaccinated children is key to our ability to provide this high-risk population with appropriate, high-quality health care.

There has been increasing recognition of hospitalization as a missed opportunity to vaccinate children whose vaccination status is not UTD, particularly in the era of population-based IISs, in which a child's vaccination status may be accessible to hospital-based providers.[19,37–40] This study demonstrates that vaccination is relevant to hospital-based pediatric care because we identified variation in diagnostic testing in the hospital by vaccination status. In areas with high rates of undervaccination, there may be spillover effects for resource use in hospitals and health systems because more children without UTD vaccination status will be seen in hospital care settings. Better integration of IISs into hospital EMRs may help hospital-based providers more accurately assess the risk of VPDs for children who are undervaccinated and present with ARTI. Access to high-quality, accurate vaccination data at the point of care will allow us to focus future efforts on safely and effectively reducing nonspecific diagnostic testing in this population. Hospital-based quality improvement efforts have shown improvement in vaccination rates for high-risk children who are hospitalized, and hospitals should continue to provide catch-up vaccinations during hospitalization when clinically appropriate.[37,38]

One limitation of this study is the use of provider-documented vaccination status as our predictor variable rather than the child's actual vaccination status. Provider-documented vaccination status is often inaccurate when compared with statewide vaccine registries.[19] We hypothesize that provider-documented vaccination status in this study was likely obtained via parent report; however, it is possible that providers used their local population-based IIS registries or outpatient vaccination records to obtain this information. In our sensitivity analysis, using IIS UTD status, we saw similar point estimates to provider-documented UTD status, suggesting provider-documented UTD status most likely reflects the information acted on by the provider in medical decision-making at the point of care. However, we lack sufficient power to detect significant differences in this subsample. Additionally, by categorizing UTD as binary (yes or no), we were unable to evaluate the effect of missing specific vaccines related to ARTI. The high rate of provider-documented UTD status that we observed also limited the power of our study to detect differences, despite a large sample size.

This study was a retrospective cohort study; thus we cannot make any causal inferences between vaccination status and subsequent testing and treatment. We adjusted for the possible confounders that were measured in this study. However, we are unable to adjust for other potential causes of bias. There was a high percentage of children documented with UTD vaccination status in this study, and there is a possibility that not being documented with an UTD vaccination status serves as a proxy for other important patient-level factors that could influence clinical care.

All of the hospitals in this study were academic children's hospitals.

Although geographically dispersed, they may not be representative of all children's hospitals or community-based settings where many children are hospitalized for ARTI.[41] Additionally, although we included variables such as ICU admission, PMCA, and LOS to account for potential differences in acuity of illnesses, these proxy measures are imperfect, and it is unknown how other clinical characteristics interact with vaccination status to influence the care children receive for ARTI.

CONCLUSIONS

Children with ARTI who presented to the hospital and whose vaccination status was documented as not UTD had higher odds of receiving laboratory tests compared with children whose vaccination status was documented as UTD. Most additional laboratory tests done were not specific for VPDs, and we identified no increased odds of receiving treatment. Not only does undervaccination place children at risk for VPDs but also there is variation in care for common ARTIs, such as croup and pneumonia, by vaccination status, with higher use of diagnostic testing for children who are undervaccinated.

ACKNOWLEDGMENT

We thank Dr Mangione-Smith for her contributions to the project.

ABBREVIATIONS

aOR: adjusted oddsratio
ARTI: acute respiratory tract illness
CAP: community-acquired pneumonia
CBC: complete bloodcell
CI: confidence interval
CRP: C-reactive protein
ED: emergency department
EMR: electronic medical record
IIS: immunization information system
LOS: length ofstay
PHIS: Pediatric Health Information System
PMCA: Pediatric Medical Complexity Algorithm
UTD: up-to-date
VPD: vaccine-preventable disease

PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: Some of the data for this article were obtained through support from National Heart, Lung, and Blood Institute grant 1R01HL121067-01 (principal investigator: Rita Mangione-Smith, MD, MPH). Funded by the National Institutes of Health (NIH).

POTENTIAL CONFLICT OF INTEREST: Dr Hofsetter previously received research support from Pfizer Independent Grants for Learning and Change; the other authors have indicated they have no potential conflicts of interest to disclose.

REFERENCES

1. Hasegawa K, Tsugawa Y, Brown DF, Mansbach JM, Camargo CA Jr. Trends in bronchiolitis hospitalizations in the United States, 2000-2009. *Pediatrics*. 2013;132(1):28–36
2. Hall CB, Weinberg GA, Iwane MK, et al. The burden of respiratory syncytial virus infection in young children. *N Engl J Med*. 2009;360(6):588–598
3. Jain S, Williams DJ, Arnold SR, et al; CDC EPIC Study Team. Community-acquired pneumonia requiring hospitalization among U.S. children. *N Engl J Med*. 2015;372(9):835–845
4. Keren R, Luan X, Localio R, et al; Pediatric Research in Inpatient Settings (PRIS) Network. Prioritization of comparative effectiveness research topics in hospital pediatrics. *Arch Pediatr Adolesc Med*. 2012;166(12):1155–1164
5. Johnson D. Croup. *BMJ Clin Evid*. 2009;2009:321
6. Moorman JE, Person CJ, Zahran HS; Centers for Disease Control and Prevention (CDC). Asthma attacks among persons with current asthma - United States, 2001-2010. *MMWR Suppl*. 2013;62(3):93–98
7. Brogan TV, Hall M, Williams DJ, et al. Variability in processes of care and outcomes among children hospitalized with community-acquired pneumonia. *Pediatr Infect Dis J*. 2012;31(10):1036–1041
8. Kronman MP, Hersh AL, Feng R, et al. Ambulatory visit rates and antibiotic prescribing for children with pneumonia, 1994-2007. *Pediatrics*. 2011;127(3):411–418
9. Christakis DA, Cowan CA, Garrison MM, et al. Variation in inpatient diagnostic testing and management of bronchiolitis. *Pediatrics*. 2005;115(4):878–884
10. Macias CG, Mansbach JM, Fisher ES, et al. Variability in inpatient management of children hospitalized with bronchiolitis. *Acad Pediatr*. 2015;15(1):69–76
11. Tyler A, McLeod L, Beaty B, et al. Variation in inpatient croup management and outcomes. *Pediatrics*. 2017;139(4):e20163582
12. Glanz JM, McClure DL, Magid DJ, et al. Parental refusal of pertussis vaccination is associated with an

increased risk of pertussis infection in children. *Pediatrics*. 2009;123(6):1446–1451

13. Glanz JM, McClure DL, O'Leary ST, et al. Parental decline of pneumococcal vaccination and risk of pneumococcal related disease in children. *Vaccine*. 2011;29(5):994–999
14. Glanz JM, Narwaney KJ, Newcomer SR, et al. Association between undervaccination with diphtheria, tetanus toxoids, and acellular pertussis (DTaP) vaccine and risk of pertussis infection in children 3 to 36 months of age. *JAMA Pediatr*. 2013;167(11):1060–1064
15. Zachariah P, Posner A, Stockwell MS, et al. Vaccination rates for measles, mumps, rubella, and influenza among children presenting to a pediatric emergency department in New York City. *J Pediatric Infect Dis Soc*. 2014;3(4):350–353
16. Glanz JM, Newcomer SR, Narwaney KJ, et al. A population-based cohort study of undervaccination in 8 managed care organizations across the United States. *JAMA Pediatr*. 2013;167(3):274–281
17. Ferson MJ. Immunisation state and its documentation in hospital patients. *Arch Dis Child*. 1990;65(7):763–767
18. Ezeanolue E, Harriman K, Hunter P, Korger A, Pellegrini C. Contraindications and Precautions. General Best Practice Guidelines for Immunization: Best Practices Guidance of the Advisory Committee on Immunization Practices (ACIP). 2019. https://www.cdc.gov/vaccines/hcp/acip-recs/general-recs/contraindications.html. Accessed September 17, 2019
19. Bryan MA, Hofstetter AM, deHart MP, Zhou C, Opel DJ. Accuracy of provider-documented child immunization status at hospital presentation for acute respiratory illness. *Hosp Pediatr*. 2018;8(12):769–777
20. Williams ER, Meza YE, Salazar S, Dominici P, Fasano CJ. Immunization histories given by adult caregivers accompanying children 3-36 months to the emergency department: are their histories valid for the Haemophilus influenzae B and pneumococcal vaccines? *Pediatr Emerg Care*. 2007;23(5):285–288
21. Goldstein KP, Kviz FJ, Daum RS. Accuracy of immunization histories provided by adults accompanying preschool children to a pediatric emergency department. *JAMA*. 1993;270(18):2190–2194
22. Bradley JS, Byington CL, Shah SS, et al; Pediatric Infectious Diseases Society; Infectious Diseases Society of America. Executive summary: the management of community-acquired pneumonia in infants and children older than 3 months of age: clinical practice guidelines by the Pediatric Infectious Diseases Society and the Infectious Diseases Society of America. *Clin Infect Dis*. 2011;53(7):617–630
23. Ralston SL, Lieberthal AS, Meissner HC, et al; American Academy of Pediatrics. Clinical practice guideline: the diagnosis, management, and prevention of bronchiolitis [published correction appears in *Pediatrics*. 2015;136(4):782]. *Pediatrics*. 2014;134(5). Available at: www.pediatrics.org/cgi/content/full/134/5/e1474
24. Dayal A, Alvarez F. The effect of implementation of standardized, evidence-based order sets on efficiency and quality measures for pediatric respiratory illnesses in a community hospital. *Hosp Pediatr*. 2015;5(12):624–629
25. Williams DJ, Hall M, Shah SS, et al. Narrow vs broad-spectrum antimicrobial therapy for children hospitalized with pneumonia. *Pediatrics*. 2013;132(5). Available at: www.pediatrics.org/cgi/content/full/132/5/e1141
26. Bradley JS, Byington CL, Shah SS, et al; Pediatric Infectious Diseases Society; Infectious Diseases Society of America. The management of community-acquired pneumonia in infants and children older than 3 months of age: clinical practice guidelines by the Pediatric Infectious Diseases Society and the Infectious Diseases Society of America. *Clin Infect Dis*. 2011;53(7):e25–e76
27. Washington State Department of Health. Public Health Immunizatoin Measures by County. 2018. Available at: https://www.doh.wa.gov/DataandStatisticalReports/HealthDataVisualization/ImmunizationDataDashboards/PublicHealthMeasures. Accessed September 17, 2019
28. Simon TD, Cawthon ML, Stanford S, et al; Center of Excellence on Quality of Care Measures for Children With Complex Needs (COE4CCN) Medical Complexity Working Group. Pediatric Medical Complexity Algorithm: a new method to stratify children by medical complexity. *Pediatrics*. 2014;133(6). Available at: www.pediatrics.org/cgi/content/full/133/6/e1647
29. Russell K, Blanton L, Kniss K, et al. Update: influenza activity–United States, October 4, 2015-February 6, 2016. *MMWR Morb Mortal Wkly Rep*. 2016;65(6):146–153
30. Centers for Disease Control and Prevention. Recommended child and adolescent immunization schedule for ages 18 years or younger. Available at: https://www.cdc.gov/vaccines/schedules/downloads/child/0-18yrs-child-combined-schedule.pdf. Accessed September 29, 2017
31. Ralston S, Garber M, Narang S, et al. Decreasing unnecessary utilization in acute bronchiolitis care: results from the value in inpatient pediatrics network. *J Hosp Med*. 2013;8(1):25–30
32. Coon ER, Young PC, Quinonez RA, et al. 2017 update on pediatric medical overuse: a review. *JAMA Pediatr*. 2018;172(5):482–486
33. Ralston SL, Garber MD, Rice-Conboy E, et al; Value in Inpatient Pediatrics Network Quality Collaborative for Improving Hospital Compliance with AAP Bronchiolitis Guideline (BQIP). A multicenter collaborative to reduce unnecessary care in inpatient bronchiolitis. *Pediatrics*. 2016;137(1):e20150851
34. Ambroggio L, Thomson J, Murtagh Kurowski E, et al. Quality improvement methods increase appropriate antibiotic prescribing for childhood pneumonia. *Pediatrics*. 2013;131(5). Available at: www.pediatrics.org/cgi/content/full/131/5/e1623
35. Quinonez RA, Garber MD, Schroeder AR, et al. Choosing wisely in pediatric hospital medicine: five opportunities for improved healthcare value. *J Hosp Med*. 2013;8(9):479–485

36. Parikh K, Hall M, Mittal V, et al. Establishing benchmarks for the hospitalized care of children with asthma, bronchiolitis, and pneumonia. *Pediatrics*. 2014;134(3): 555–562

37. Pahud B, Clark S, Herigon JC, et al. A pilot program to improve vaccination status for hospitalized children. *Hosp Pediatr*. 2015;5(1):35–41

38. Milet B, Chuo J, Nilan K, et al. Increasing immunization rates in infants with severe chronic lung disease: a quality improvement initiative. *Hosp Pediatr*. 2018;8(11):693–698

39. Weddle G, Jackson MA. Vaccine eligibility in hospitalized children: spotlight on a unique healthcare opportunity. *J Pediatr Health Care*. 2014;28(2):148–154

40. Mihalek AJ, Kysh L, Pannaraj PS. Pediatric inpatient immunizations: a literature review. *Hosp Pediatr*. 2019; 9(7):550–559

41. Leyenaar JK, Ralston SL, Shieh MS, et al. Epidemiology of pediatric hospitalizations at general hospitals and freestanding children's hospitals in the United States. *J Hosp Med*. 2016; 11(11):743–749

Vaccination Status and Resource Use During Hospital Visits for Respiratory Illnesses

Mersine A. Bryan, Annika M. Hofstetter, M. Patricia deHart, Tamara D. Simon and Douglas J. Opel

Pediatrics 2019;144;
DOI: 10.1542/peds.2019-0585 originally published online October 17, 2019;

Vaccination Status and Resource Use During Hospital Visits for Respiratory Illnesses

Mersine A. Bryan, Annika M. Hofstetter, M. Patricia deHart, Tamara D. Simon and Douglas J. Opel

Pediatrics 2019;144;
DOI: 10.1542/peds.2019-0585 originally published online October 17, 2019;