RESEARCH ARTICLE

Vaccination Status and Adherence to Quality Measures for Acute Respiratory Tract Illnesses

Mersine A. Bryan, MD, MPH,[a,b] Annika M. Hofstetter, MD, PhD, MPH,[a,b] Tamara D. Simon, MD, MSPH,[a,b] Chuan Zhou, PhD,[a,b] Derek J. Williams, MD, MPH,[c] Amy Tyler, MD, MSCS,[d] Chén C. Kenyon, MD, MSHP,[e] Joyee G. Vachani, MD, MEd,[f] Douglas J. Opel, MD, MPH,[a,b] Rita Mangione-Smith, MD, MPH[a,b]

ABSTRACT

OBJECTIVES: To assess the relationship between vaccination status and clinician adherence to quality measures for children with acute respiratory tract illnesses.

METHODS: We conducted a multicenter prospective cohort study of children aged 0 to 16 years who presented with 1 of 4 acute respiratory tract illness diagnoses (community-acquired pneumonia, croup, asthma, and bronchiolitis) between July 2014 and June 2016. The predictor variable was provider-documented up-to-date (UTD) vaccination status. Our primary outcome was clinician adherence to quality measures by using the validated Pediatric Respiratory Illness Measurement System (PRIMES). Across all conditions, we examined overall PRIMES composite scores and overuse (including indicators for care that should not be provided, eg, C-reactive protein testing in community-acquired pneumonia) and underuse (including indicators for care that should be provided, eg, dexamethasone in croup) composite subscores. We examined differences in length of stay, costs, and readmissions by vaccination status using adjusted linear and logistic regression models.

RESULTS: Of the 2302 participants included in the analysis, 92% were documented as UTD. The adjusted mean difference in overall PRIMES scores by UTD status was not significant (adjusted mean difference −0.3; 95% confidence interval: −1.9 to 1.3), whereas the adjusted mean difference was significant for both overuse (−4.6; 95% confidence interval: −7.5 to −1.6) and underuse (2.8; 95% confidence interval: 0.9 to 4.8) composite subscores. There were no significant adjusted differences in mean length of stay, cost, and readmissions by vaccination status.

CONCLUSIONS: We identified lower adherence to overuse quality indicators and higher adherence to underuse quality indicators for children not UTD, which suggests that clinicians "do more" for hospitalized children who are not UTD.

[a]Department of Pediatrics, University of Washington, Seattle, Washington; [b]Seattle Children's Research Institute, Seattle, Washington; [c]Division of Hospital Medicine, Department of Pediatrics, School of Medicine, Vanderbilt University and Monroe Carell Jr Children's Hospital at Vanderbilt, Nashville, Tennessee; [d]Section of Hospital Medicine, Department of Pediatrics, School of Medicine, University of Colorado and Children's Hospital Colorado, Aurora, Colorado; [e]Department of Pediatrics, School of Medicine, University of Pennsylvania and Center for Pediatric Clinical Effectiveness, Children's Hospital of Philadelphia, Philadelphia, Pennsylvania; and [f]Section of Pediatric Hospital Medicine, Department of Pediatrics, Baylor College of Medicine, Houston, Texas

www.hospitalpediatrics.org
DOI:https://doi.org/10.1542/hpeds.2019-0245

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

HOSPITAL PEDIATRICS (ISSN Numbers: Print, 2154-1663; Online, 2154-1671).

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

FUNDING: Supported by National Heart, Lung, and Blood Institute grant 1R01HL121067-01 (principal investigator: Dr Mangione-Smith). Funded by the National Institutes of Health (NIH).

POTENTIAL CONFLICT OF INTEREST: Dr Hofstetter 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.

Dr Bryan conceptualized the study design, conducted the data analysis, and wrote the first draft of the manuscript; Drs Hofstetter, Simon, and Opel contributed to the study design and interpretation of study data and critically reviewed the manuscript to provide key intellectual content; Dr Zhou assisted with the statistical analyses and interpretation of results and critically reviewed and revised the manuscript; Drs Williams, Kenyon, Tyler, and Vachani coordinated and supervised data collection at 1 of the 5 sites, contributed to the interpretation of results, and critically reviewed and revised the manuscript; Dr Mangione-Smith secured funding for the study, coordinated and supervised data collection at 1 of the 5 sites, contributed to the study conceptualization and design and interpretation of results, and critically reviewed and revised the manuscript; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Children who are undervaccinated are at a greater risk for acute respiratory tract illnesses (ARTIs), including those caused by pneumococcus, *Haemophilus influenzae,* pertussis, and influenza.[1,2] In addition to disease-specific risks associated with undervaccination, children who are undervaccinated have higher rates of all-cause hospital admission and higher rates of emergency department (ED) visits compared with children who are fully vaccinated.[3] Because 27% to 84% of hospitalized children are undervaccinated at the time of admission, variation in hospital care received by children who are undervaccinated is important to understand.[4–7] Recent data suggest that children who are undervaccinated presenting to the hospital with ARTI experience greater resource use, with a higher odds of receiving laboratory testing, including complete blood cell (CBC) counts, blood cultures, testing of C-reactive protein (CRP) levels, and influenza testing, compared with children who are fully vaccinated.[8]

Although there has been considerable focus on both the variation in care and on the development of quality measures for children with ARTI, the role of vaccination status in clinical decision-making for children who present to the hospital with ARTI and how it relates to process measures and outcomes is unknown.[9–12] Our primary objective for this study was to examine adherence to a validated set of quality measures for children hospitalized or seen in the ED with ARTI by vaccination status. Our secondary aim for this study was to examine the relationship between vaccination status and outcomes, including length of stay (LOS), cost of care, and readmissions. We hypothesized that there would be lower clinician adherence to quality measures, longer LOS, and higher cost among children who were undervaccinated presenting to the hospital with ARTI compared with children who were fully vaccinated.

METHODS

Study Population

We conducted a prospective cohort study of children who presented with ARTI between July 2014 and June 2016 to 5 freestanding academic children's hospitals in the United States participating in the Pediatric Research in Inpatient Settings Network. ARTI was defined as community-acquired pneumonia (CAP), croup, asthma, and bronchiolitis. These ARTIs were included in this study because vaccine-preventable diseases, such as pneumococcal disease, *Haemophilus influenzae* disease, pertussis, and influenza, were potentially relevant to the differential diagnosis, clinical presentation, and subsequent medical decision-making for each condition. 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. All children included in the study who were diagnosed with CAP, asthma, and bronchiolitis were admitted to the hospital. Children with croup were either admitted to the hospital or discharged from the ED. We opted to include children with croup who were discharged from the ED given the lower rates of hospital admission for croup compared with the other 3 conditions. If a child had >1 hospitalization during the study period, only the first hospitalization was included in this analysis.

Subjects were excluded if they (1) had an underlying condition that would alter the routine childhood vaccination schedule (including requiring additional vaccines), such as immunodeficiencies, HIV, or asplenia, per the recommendations of the Advisory Committee on Immunization Practices[13] or (2) had a chronic medical condition that would alter the standard of care for ARTI, including a history of cardiac disease requiring baseline medication, anatomic airway abnormalities, cystic fibrosis, neuromuscular disease, bronchopulmonary dysplasia, immunodeficiency, or chronic lung disease.[14] The study procedures were reviewed and approved by the institutional review boards of the participating hospitals or the Western Institutional Review Board.

Variables

The primary independent 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. Although previous studies have revealed that provider-documented UTD status may not be reflective of true vaccination status,[6,15,16] we selected it as our independent variable because it represented the information the provider had at the point of care when making clinical decisions during the ED visit or hospitalization. All hospitals in the study had a specific vaccination question included in their EMR note templates for ED notes and admission history and physicals. Subjects were excluded if there was no provider documentation of vaccination status in the EMR. At the time of this study, none of the hospitals had vaccination data from population-based immunization information systems integrated into their EMRs. Thus, provider-documented status was presumed to be the only available information about vaccination status in the EMR. There was no uniform question specifically about influenza vaccines for all institutions. Whether influenza vaccination was included in being UTD depended on whether the provider documenting UTD status defined it as such.

We used the Pediatric Respiratory Illness Measurement System (PRIMES) to measure adherence to quality measures.[14] PRIMES is a set of process-of-care quality indicators that can be used to assess the clinical management of children hospitalized with the following respiratory conditions: CAP, croup, asthma, and bronchiolitis.[14,17] Indicators were developed on the basis of a literature review and clinical practice guidelines and were validated by using a modified Delphi method.[14,18] We examined overall adherence to the condition-specific PRIMES indicators for each child (scale 0–100) and the overuse and underuse composite scores.[19] Overuse composite scores included the quality indicators for processes of care that should not occur (eg, obtaining a CRP test in children admitted with uncomplicated CAP).[20] Underuse composite scores included quality indicators for processes of care that should occur (eg, giving a dose of dexamethasone to children presenting with croup). For all

scores, higher scores indicated increased adherence to the indicators and higher quality care (Supplemental Table 4).

Each hospital in the study contributes data to the Pediatric Health Information System database. LOS, same-cause 30-day ED and/or inpatient reuse, and cost data were obtained from the Pediatric Health Information System database for each patient. All costs were inflation adjusted to 2016 dollars.

Covariates

Covariates of interest included child age, 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[21] (although participants >6 years of age were aggregated because of the small sample size). Chronic disease status was determined by using the Pediatric Medical Complexity Algorithm (PMCA).[22] A chart review was performed for all subjects with complex chronic disease to ensure that they met study eligibility criteria. The month of presentation was included to account for seasonal trends and categorized into influenza season (October to March) and non–influenza season (April to September).[23]

Sensitivity Analysis

As an exploratory analysis, we examined the following additional covariates: (1) primarily speaking a language other than English at home (ie, limited English proficiency), (2) parent income level, (3) parent education level, and (4) parent-reported difficulty in accessing care. These variables were obtained from a parent-reported survey collected within 72 hours of admission. The difficulty in accessing care measure was from the 2009–2010 National Survey of Children with Special Health Care Needs.[24] Parents responded to the question, "In the last 6 months, did you have any difficulties or delays getting care for your child because there were waiting lists, backlogs, or other problems getting an appointment?" Responses were categorized as binary (yes or no). Further information on survey data collection has been previously published.[19]

Analysis

Summary statistics were used to describe the cohort of subjects. We used χ^2 tests and bivariable logistic regression to assess the relationship between covariates and vaccination status, the relationship between covariates and the outcome variables, and the relationship between UTD status and our outcome variables. To test the independent association of vaccination status and the outcome variables, we used multivariable logistic regression models that included covariates (race and/or ethnicity, PMCA, and season of presentation) with a significant ($P < .05$) relationship with vaccination status and the outcome variables. Hospital site was included as a fixed effect in all multivariable models. We generated multivariable linear regression models to examine the relationship between vaccination status and (1) adherence to condition-specific PRIMES indicators, (2) overuse composite PRIMES scores, (3) underuse composite PRIMES scores, (4) LOS, and (5) cost. We examined results as the adjusted mean difference for continuous outcomes for children documented as not UTD compared with those documented as UTD. LOS and cost were truncated at the 99th percentile to prevent the skewed distribution from distorting SEs in the multivariable analyses. Observations above the 99th perentile were assigned the 99th percentile value; this occurred for 16 LOS observations and 24 cost observations. Models used to examine cost as the outcome were additionally adjusted for LOS. We generated multivariable logistic regression models to examine the relationship between vaccination status and 30-day same-cause readmission to the ED or inpatient setting.

RESULTS

Of 2380 children identified with ARTI, 46 (2%) were excluded for underlying conditions that would alter the routine childhood vaccination schedule and 32 (1%) had no documentation of vaccine status in their EMRs. Of the remaining 2302 participants included in the analysis, the mean age was 3.6 years (SD 3.7 years), 59% were boys, 40% were white, and 57% were publicly insured (Table 1). There were 568 (24%) diagnosed with CAP, 343 (15%) with croup, 653 (28%) with asthma, and 738 (32%) with bronchiolitis. Most (92%) were UTD on vaccinations by provider documentation. Vaccination rates by hospital ranged from 3% of subjects being documented as not UTD (hospitals 1 and 5) to 17% documents as not UTD (hospital 2) (Table 1). Race and/or ethnicity, PMCA, season of presentation, hospital, and diagnosis were all significantly associated with provider-documented UTD status (Table 1). We did not identify any significant associations among respondents to the parent-reported survey items (limited English proficiency, parent income, parent education level, and parent-reported difficulty in accessing care) with provider-documented vaccination status (Table 1).

Across all conditions, the adjusted mean difference in the overall PRIMES score by UTD status was not statistically significant (Table 2). However, there was a significant adjusted mean difference in overuse and underuse composite PRIMES scores by UTD status. Compared with children who were UTD, children not UTD had significantly lower mean overuse PRIMES composite scores and significantly higher mean underuse PRIMES composite scores.

In condition-specific adjusted models, there was no significant adjusted mean difference in the overall PRIMES score by UTD status. For children with CAP, however, children who were not UTD had significantly lower adjusted mean overuse composite PRIMES scores and significantly higher adjusted mean underuse composite PRIMES scores than children who were UTD (Table 2). For croup, children who were not UTD had significantly lower adjusted overuse composite PRIMES score compared with children who were UTD (Table 2). There were no differences in adherence to PRIMES quality indicators by vaccination status for children with asthma and bronchiolitis.

In adjusted models, we identified no significant differences in LOS in hours or costs for children who were documented as not UTD (versus UTD) (Table 3). There were no differences in readmissions for children

TABLE 1 Demographic Variables and Covariates by Provider-Documented Vaccination Status

	All Participants (N = 2305)	UTD (n = 2126)	Not UTD (n = 179)	P
Mean age (SD), y	3.5 (3.7)	3.6 (3.8)	3.0 (3.2)	.06
Sex, *n* (%)				
Male	1364 (59)	1253 (59)	111 (62)	.43
Race and/or ethnicity, *n* (%)				.03
White	910 (40)	836 (39)	74 (34)	
African American	512 (22)	485 (23)	27 (15)	
Hispanic	556 (24)	500 (24)	56 (31)	
Other	307 (13)	285 (13)	22 (12)	
Missing	17 (1)	17 (1)	0 (0)	
Insurance, *n* (%)				
Private	999 (43)	924 (44)	75 (42)	.67
Public	1303 (57)	1199 (56)	104 (58)	
Missing	3 (0)	3 (0)	0 (0)	
PMCA, *n* (%)				.05
Nonchronic	1278 (56)	1162 (55)	116 (65)	
Noncomplex chronic	920 (40)	865 (41)	55 (31)	
Complex chronic	101 (4)	93 (4)	8 (4)	
Missing	6 (0)	6 (0)	0 (0)	
Limited English proficiency				.98
Yes	229 (10)	211 (10)	18 (10)	
Missing	14 (1)	14 (1)	0 (0)	
Parent income				.24
<$31 000	745 (32)	680 (32)	65 (36)	
$31 000–$50 000	353 (15)	322 (15)	31 (17)	
>$50 000	840 (36)	784 (37)	56 (31)	
Missing	364 (16)	337 (16)	27 (15)	
Parent education level				.15
Less than high school	234 (10)	223 (11)	11 (6)	
High school	1493 (65)	1368 (64)	125 (70)	
More than high school	553 (24)	511 (24)	42 (23)	
Missing	22 (1)	21 (1)	1 (1)	
Access to care				.42
No difficulty or delay	1443 (63)	1344 (63)	99 (55)	
Any difficulty or delay	610 (27)	562 (26)	48 (27)	
Missing	249 (11)	217 (10)	32 (18)	
ICU admission, *n* (%)	145 (6)	130 (6)	15 (8)	.43
Seasonality, *n* (%)				.002
April to September	806 (35)	762 (36)	44 (25)	
October to March	1496 (65)	1361 (64)	135 (75)	
Hospital, *n* (%)				<.001
1	528 (23)	513 (24)	15 (8)	
2	488 (21)	403 (19)	85 (47)	
3	468 (20)	431 (20)	37 (21)	
4	278 (12)	250 (12)	28 (16)	
5	540 (23)	526 (25)	14 (8)	

who were not UTD compared with those who were documented as UTD.

DISCUSSION

In this large, multisite, prospective cohort of children with ARTI, we examined the association between adherence to evidence-based quality measures and provider-documented child vaccination status. We identified that children with ARTI who were documented at hospital presentation as not UTD had similar adherence to overall quality measures as children who were documented as UTD. However, when examining PRIMES scores across all 4 conditions, we identified differences in overuse and underuse composites by vaccination status, with lower adherence to overuse quality measures and higher adherence to underuse quality measures for children who were not UTD. Despite differential adherence to quality measures by vaccination status, we identified no significant differences in the LOS or cost for children who were undervaccinated and admitted with ARTI compared with children who were fully vaccinated.

Lower scores for overuse quality measures and higher scores for underuse quality measures may indicate a propensity for providers to "do more" for children who present to the hospital with ARTI and are documented as undervaccinated (ie, adhere less to quality indicators for processes of care that should not occur and adhere more to quality indicators for processes of care that should occur). This finding is consistent with previous work examining variation in testing and treatment by vaccination status for children presenting to the hospital with ARTI, in which children who were undervaccinated had a higher odds of receiving laboratory testing. Of note, differences in the overuse and underuse composite scores were only identified for CAP and croup. The overuse indicators for CAP and croup are largely related to diagnostic testing, including recommendations against getting routine blood cultures, CRP tests, and erythrocyte sedimentation rate (ESR) tests for CAP and chest radiographs for croup. We may have only seen differences in overuse and underuse indicators by vaccination status in

TABLE 1 Continued

	All Participants ($N = 2305$)	UTD ($n = 2126$)	Not UTD ($n = 179$)	P
Diagnosis, *n* (%)				<.001
CAP	568 (24)	504 (24)	64 (36)	
Croup	343 (15)	314 (15)	29 (16)	
Asthma	653 (28)	617 (29)	36 (20)	
Bronchiolitis	738 (32)	688 (32)	50 (28)	

CAP and croup (and not in asthma or bronchiolitis) because clinicians may face increased diagnostic uncertainty with these 2 conditions and therefore have to consider vaccine-preventable diseases in their differential diagnosis and subsequent medical decision-making. In further work in this area, researchers should consider examining variation in care by vaccination status for children with other potential vaccine-related illnesses and chief complaints.

It is also noteworthy that providers appeared to do more for children with ARTI who were undervaccinated not only when it was consistent with evidence-based recommendations (higher underuse scores) but also when it was not (lower overuse scores). In an era focused on deimplementation, safely doing less, and reducing low-value care,[25,26] it is important to consider the impact that low vaccination rates within a population can have on these efforts. Additionally, further work should be done to evaluate whether improving vaccination rates within the outpatient population can enhance efforts to safely do less in children who are hospitalized.

Our choice to use provider-documented vaccination status at the time of hospital presentation was meant to reflect the information available to the provider at the point of care. Provider-documented vaccination status is often inaccurate when compared with statewide vaccine registries, with most misclassifications in the direction of being documented as UTD when not truly UTD.[6] It is unknown how documentation of vaccination status plays a role in clinical decision-making for children who present to the hospital with ARTI. With such a high percentage of children being documented as UTD in this study, there is a possibility that being documented as not UTD serves as a proxy for other important patient- and family-level factors with potential to influence patient care, such as health literacy. Understanding how patient- and family-level factors influence provider decision-making is key to providing high-quality care to children who present to the hospital with acute illnesses.

With the improvement in population-based immunization registries over the past decade, there has been a renewed focus on hospitalization as an opportunity to vaccinate.[4,15,27–29] Despite this, there are significant barriers to accurately identifying hospitalized children who are

TABLE 2 Adjusted PRIMES Scores and Adjusted Mean Differences in PRIMES Scores for Children Who Were Not UTD Compared With Children Who Were UTD

	Overall PRIMES Score (95% CI)	Overuse Composite (95% CI)	Underuse Composite (95% CI)
All conditions			
UTD	85.1 (83.7 to 86.4)	81.9 (79.3 to 84.4)**	83.8 (82.2 to 85.4)**
Not UTD	84.7 (82.7 to 86.8)	77.3 (73.4 to 81.1)**	86.6 (84.1 to 89.1)**
Difference	−0.3 (−1.9 to 1.3)	−4.6 (−7.5 to −1.6)**	2.8 (0.9 to 4.8)**
CAP			
UTD	84.5 (81.3 to 87.7)	86.0 (81.4 to 90.7)**	82.4 (78.5 to 86.3)*
Not UTD	81.7 (77.2 to 86.2)	78.6 (72.1 to 85.1)**	86.4 (80.9 to 91.9)*
Difference	−2.7 (−6.0 to 0.5)	−7.4 (−12.1 to −2.7)**	4.0 (0.0 to 7.9)*
Croup			
UTD	82.5 (78.2 to 86.7)	39.3 (14.6 to 64.1)*	85.2 (81.9 to 88.6)
Not UTD	82.4 (75.9 to 88.8)	8.7 (−27.6 to 44.9)*	87.2 (82.2 to 92.2)
Difference	−0.1 (−5.0 to 4.8)	−30.7 (−58.2 to −3.2)*	2.0 (−1.8 to 5.8)
Asthma			
UTD	81.0 (75.1 to 86.7)	97.8 (92.2 to 103.3)	75.1 (67.6 to 82.6)
Not UTD	81.3 (75.3 to 87.6)	98.6 (92.6 to 104.7)	75.3 (67.1 to 83.4)
Difference	0.4 (−2.3 to 3.1)	0.9 (−1.8 to 3.5)	0.1 (−3.4 to 3.7)
Bronchiolitis			
UTD	89.7 (87.8 to 91.6)	94.8 (92.1 to 97.5)	82.6 (79.9 to 85.3)
Not UTD	88.9 (86.1 to 91.7)	93.5 (89.5 to 97.5)	82.3 (78.3 to 86.2)
Difference	−0.8 (−2.9 to 1.4)	−1.3 (−4.3 to 1.7)	−0.3 (−3.3 to 2.7)

Adjusted for race and/or ethnicity, PMCA, season of admission, and hospital site. CI, confidence interval.
** $P < .01$; * $P < .05$.

TABLE 3 Secondary Outcomes and Adjusted Mean Differences in LOS and Cost by Vaccination Status

	Unadjusted LOS (95% CI), h	Adjusted LOS (95% CI), h	Unadjusted Cost (95% CI), $	Adjusted Cost (95% CI), $
All conditions				
UTD	49.9 (48.3 to 51.5)**	55.3 (50.6 to 60.1)	5270 (5097 to 5443)**	3972 (3582 to 4361)
Not UTD	57.9 (52.4 to 63.4)**	57.7 (50.4 to 65.1)	6187 (5591 to 6782)**	4315 (3719 to 4910)
Difference	8.0 (2.3 to 13.8)**	2.4 (−3.3 to 8.2)	916 (297 to 1537)**	343 (−117 to 803)
CAP				
UTD	59.7 (55.8 to 63.6)	60.3 (48.0 to 72.6)	6637 (6226 to 7049)	4420 (3439 to 5400)
Not UTD	69.0 (58.1 to 79.9)	64.0 (46.8 to 81.3)	7678 (6523 to 8832)	5133 (3773 to 6493)
Difference	9.3 (−2.3 to 20.9)	3.7 (−8.8 to 16.2)	1040 (−185 to 2266)	713 (−259 to 1687)
Croup				
UTD	34.1 (31.3 to 36.8)***	31.0 (23.1 to 38.8)	3022 (2675 to 3369)**	3238 (2408 to 4069)
Not UTD	49.7 (40.6 to 58.7)***	39.3 (27.5 to 51.2)	4840 (3698 to 5983)**	3558 (2293 to 4824)
Difference	15.6 (6.1 to 25.0)***	8.3 (−0.6 to 17.3)	1818 (624 to 3012)**	320 (−635 to 1276)
Asthma				
UTD	39.3 (37.5 to 41.2)	41.4 (25.0 to 57.8)	4930 (4678 to 5182)	5147 (3430 to 6864)
Not UTD	41.3 (33.7 to 49.0)	40.7 (22.8 to 58.6)	5305 (4261 to 6439)	5235 (3362 to 7108)
Difference	2.0 (−5.9 to 9.9)	−0.7 (−8.4 to 7.1)	375 (−700 to 1449)	88 (−723 to 900)
Bronchiolitis				
UTD	59.3 (56.2 to 62.5)	61.1 (50.5 to 71.8)	5599 (5291 to 5906)	4260 (3475 to 5045)
Not UTD	60.5 (48.9 to 72.1)	59.3 (43.7 to 74.9)	5694 (4552 to 6835)	4070 (2934 to 5205)
Difference	1.1 (−10.9 to 13.1)	−1.9 (−13.7 to 10.0)	95 (−1087 to 1277)	−190 (−1044 to 633)

All models were adjusted for race and/or ethnicity, PMCA, season of admission, and site. Cost models were also adjusted for LOS. CI, confidence interval.
*** $P < .001$; ** $P < .01$.

undervaccinated.[5,6,15,16] Hospital-based quality improvement efforts have revealed improvement in vaccination rates for high-risk children who are hospitalized.[4,30] Better integration of population-based immunization data into hospital EMRs may bolster efforts to provide catch-up vaccinations to children who are hospitalized. Consistent with the results of our study, however, improved recognition of true vaccination status may also result in hospital-based providers doing more for hospitalized children who are undervaccinated. Continued efforts should be focused on providing high-value care to children who are hospitalized and undervaccinated, including administering vaccinations when appropriate and clinically indicated.

In this study, we examined the association of documented vaccination status and adherence to quality indicators. Among variables that were measured, we were able to control for potential confounders of this association. However, we could not account for unmeasured variables, such as illness severity, that may confound the relationship between vaccination status and adherence to respiratory quality measures.[19]

Despite a large sample size, we had a low number of children who were not UTD by provider documentation, which limited the power of our study to detect differences. By categorizing UTD status as a binary yes or no variable, we were unable to evaluate the effect of missing specific vaccines related to ARTI. Lastly, all the hospitals in this study were academic children's hospitals. They may not be representative of all care settings where children are hospitalized with ARTI, such as community-based settings.

CONCLUSIONS

We identified lower adherence to overuse quality indicators and higher adherence to underuse quality indicators among children who were not UTD, suggesting that clinicians do more for hospitalized children who are undervaccinated. The identified differences in adherence to quality measures by vaccination status were significant for children hospitalized with croup or CAP, whereas children with asthma and bronchiolitis had similar adherence regardless of vaccination status. Future efforts should be focused on improving vaccination rates for children who are hospitalized and examining how this relates to subsequent provision of high-value care in this high-risk population.

REFERENCES

1. 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
2. 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
3. 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

4. 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

5. Bell LM, Pritchard M, Anderko R, Levenson R. A program to immunize hospitalized preschool-aged children: evaluation and impact. *Pediatrics*. 1997;100(2, pt 1):192–196

6. 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

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

8. Bryan MA, Hofstetter AM, deHart MP, Simon TD, Opel DJ. Vaccination status and resource use during hospital visits for respiratory illnesses. *Pediatrics*. 2019;144(5):e20190585

9. Florin TA, Byczkowski T, Ruddy RM, Zorc JJ, Test M, Shah SS. Variation in the management of infants hospitalized for bronchiolitis persists after the 2006 American Academy of Pediatrics bronchiolitis guidelines. *J Pediatr*. 2014;165(4):786–792.e1

10. Christakis DA, Cowan CA, Garrison MM, Molteni R, Marcuse E, Zerr DM. Variation in inpatient diagnostic testing and management of bronchiolitis. *Pediatrics*. 2005;115(4):878–884

11. 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

12. Tyler A, McLeod L, Beaty B, et al. Variation in inpatient croup management and outcomes. *Pediatrics*. 2017;139(4):e20163582

13. Centers for Disease Control and Prevention. Altered immunocompetence. General best practice guidelines for immunization: best practices guidance of the Advisory Committee on Immunization Practices (ACIP). Available at: https://www.cdc.gov/vaccines/hcp/acip-recs/general-recs/immunocompetence.html. Accessed May 14, 2018

14. Mangione-Smith R, Roth CP, Britto MT, et al. Development and testing of the Pediatric Respiratory Illness M$_e$asurement System (PRIMES) quality indicators. *Hosp Pediatr*. 2017;7(3):125–133

15. 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

16. 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

17. Bryan MA, Desai AD, Wilson L, Wright DR, Mangione-Smith R. Association of bronchiolitis clinical pathway adherence with length of stay and costs. *Pediatrics*. 2017;139(3):e20163432

18. Brook R. The RAND/UCLA appropriateness method. In: McCormick KA, Moore SR, Siegel RA, eds. *Clinical Practice Guidelines Development:Methodology Perspectives*. Rockville, MD: Public Health Service, US Department of Health and Human Services; 1994. 59–70

19. Mangione-Smith R, Zhou C, Williams DJ, et al; Pediatric Research in Inpatient Settings (PRIS) Network. Pediatric Respiratory Illness Measurement System (PRIMES) scores and outcomes. *Pediatrics*. 2019;144(2):e20190242

20. 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

21. Washington State Department of Health. Immunization data. 2016. Available at: https://www.doh.wa.gov/DataandStatisticalReports/HealthDataVisualization/ImmunizationDataDashboards. Accessed December 24, 2019

22. 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

23. 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

24. Centers for Disease Control and Prevention. 2009-2010 national survey of children with special health care needs. Available at: https://www.cdc.gov/nchs/data/slaits/NS_CSHCN_Questionnaire_09_10.pdf. Accessed November 15, 2019

25. Coon ER, Young PC, Quinonez RA, Morgan DJ, Dhruva SS, Schroeder AR. 2017 update on pediatric medical overuse: a review. *JAMA Pediatr*. 2018;172(5):482–486

26. Woloshin S, Schwartz LM. Overcoming overuse: the way forward is not standing still-an essay by Steven Woloshin and Lisa M Schwartz. *BMJ*. 2018;361:k2035

27. Muehleisen B, Baer G, Schaad UB, Heininger U. Assessment of immunization status in hospitalized children followed by counseling of parents and primary care physicians improves vaccination coverage: an interventional study. *J Pediatr*. 2007;151(6):704–706.e2

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

29. Centers for Disease Control and Prevention (CDC). Progress in immunization information systems - United States, 2012. *MMWR Morb Mortal Wkly Rep*. 2013;62(49):1005–1008

30. 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