RESEARCH ARTICLE

Accuracy of Provider-Documented Child Immunization Status at Hospital Presentation for Acute Respiratory Illness

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ABSTRACT

OBJECTIVES: To assess (1) the accuracy of child immunization status documented by providers at hospital presentation for acute respiratory illness and (2) the association of provider-documented up-to-date (UTD) status with immunization receipt during and after hospitalization.

METHODS: We conducted a retrospective cohort analysis of children ≤16 years old treated for asthma, croup, bronchiolitis, or pneumonia at a children's hospital between July 2014 and June 2016. Demographics, clinical characteristics, and provider-documented UTD immunization status (yes or no) at presentation were obtained from the medical record. We compared provider-documented UTD status to the gold standard: the child's UTD status as documented in the Washington State Immunization Information System (WAIIS). The sensitivity, specificity, and positive predictive value of provider-documented UTD status were calculated. We assessed the association of provider-documented UTD status and immunization during and within 30 days posthospitalization using multivariable logistic regression.

RESULTS: Among 478 eligible children, 450 (94%) had provider-documented UTD status at hospital presentation and an active WAIIS record. Overall, 92% and 42% were UTD by provider documentation and WAIIS records, respectively, with provider-documented UTD status having 98.4% sensitivity (95% confidence interval [CI]: 95.4%–99.7%), 12.2% specificity (95% CI: 8.5%–16.8%), and 44.6% positive predictive value (95% CI: 39.7%–49.5%). Per WAIIS records, 20% and 44% of children who were due for vaccines received a vaccine during or within 30 days posthospitalization, respectively. There was no significant association between provider-documented UTD status and immunization during or after hospitalization.

CONCLUSIONS: Provider-documented UTD immunization status at hospital presentation for children with respiratory illnesses overestimates UTD status, creating missed opportunities for immunization during and after hospitalization.

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For children with acute respiratory illnesses, it is crucial for clinicians to obtain accurate immunization histories to assess the risk of vaccine-preventable diseases.[1–6] Immunization information systems (IISs), which are federally supported population-based immunization registries, can be used to facilitate this, with the IIS strategic plan being focused on ensuring that "real-time, consolidated immunization data and services for all ages are available for authorized clinical, administrative, and public health users, and consumers, anytime and anywhere."[7] Although there has been progress in the proportion of children participating in IISs, there is a paucity of data on whether and how providers use IISs at the point of care to make clinical decisions.[8–10]

An alternative method for obtaining immunization status is by parent report. However, parent report is often inaccurate.[6,11–20] Clinician reliance on parent-reported immunization status may create missed opportunities for catch-up immunizations during and after hospitalization.[21] The recognition of missed opportunities during hospitalization shows promise for interventions that are implemented to promote immunization posthospitalization; however it is unknown how IISs may be used for this purpose.[21,22]

Our primary objective in this study is to assess the accuracy of provider-documented immunization status of children presenting to the hospital with acute respiratory illnesses in the IIS era. Many previous studies in which researchers detail the inaccuracy of parent report were conducted before the integration of IISs into clinical care.[15,17–20] Others have been limited by a focus on specific vaccines[11–14] and a restricted age range of participants.[11–14,16,17] We hypothesize that provider-documented immunization status on hospital admission will be less accurate than immunization status recorded in IISs. Our secondary objective was to explore whether children who were due for vaccines per the IIS at hospital admission received needed vaccines during hospitalization or within 1 month of discharge. We hypothesize that there will be missed opportunities for children to receive catch-up immunizations during and after hospitalizations.

METHODS

Study Population and Setting

We conducted a retrospective cohort study of participants ≤16 years old who presented with acute respiratory illness to a free-standing children's hospital between July 2014 and June 2016. Children were enrolled in the study if they were seen in the emergency department and admitted to the inpatient medical unit with 1 of 4 respiratory illnesses identified by using *International Classification of Diseases, 10th Revision* diagnosis codes: asthma, bronchiolitis, croup, or pneumonia. Because of limited resources, we only included children with respiratory illnesses. We focused on acute respiratory illnesses because (1) they are a common cause of pediatric hospitalization, and (2) a child's immunization status is particularly relevant given that vaccine-preventable diseases (such as pertussis, pneumococcal disease, and influenza) are featured prominently in differential diagnoses. Participants were excluded if they had a preexisting medical condition that would alter the routine childhood immunization schedule, such as immune deficiencies, HIV, or asplenia, per the recommendations of the Advisory Committee on Immunization Practices.[23]

During the study period, there was a hospital-wide policy to screen patients and provide influenza vaccines if needed during influenza season. All routine vaccines were available if ordered by a provider; however, no other system-wide efforts were in place to identify and vaccinate children who were underimmunized. Immunizations provided in the hospital are unidirectionally sent to the Washington State Immunization Information System (WAIIS) database. Hospital providers have access to WAIIS, but it is not integrated into the electronic medical record (EMR). To access the database, providers need to access a separate WAIIS Web site.

This study was approved by the Western and Washington State institutional review boards.

Immunization Status

Provider documentation of a child's immunization status on hospital admission was abstracted from either the emergency department or inpatient admission note in the EMR. EMR templates contain a field for immunizations within the "Past Medical History" section. The response options are up-to-date (UTD), not UTD, and a free-text box. The study hospital is staffed by pediatric, emergency medicine, and family medicine residents as well as pediatric attending physicians and nurse practitioners, all of whom can document a child's immunization status in the EMR. Documentation of a child's immunization status was categorized as either UTD or not. Participants were excluded if there was no EMR documentation of immunization status.

For each participant, EMR data were linked to WAIIS immunization records by using select identifiers. WAIIS records were considered the referent gold standard because WAIIS is a comprehensive statewide immunization registry that is populated by state birth records and is highly complete.[8,24] In 2016, >2100 health organizations participated in WAIIS, with 97% of children 4 months to 5 years old and 88% of adolescents 11 to 17 years old having ≥2 immunizations recorded.[25]

Participants were excluded if no WAIIS record was identified or the WAIIS record had a status of "inactive." WAIIS records are inactivated for reasons such as moving out of state or death. Participants were considered UTD according to WAIIS records if at the time of presentation, they had received all age-appropriate vaccine doses according to the Advisory Committee on Immunization Practices–recommended schedule, including influenza. Participants were considered not UTD if they were >30 days overdue for a required vaccine.[5,26] Participants were considered UTD for the influenza vaccine if they (1) presented between October and March and had received an influenza vaccine during the current season or (2) presented between April and September and had received an influenza vaccine dose in the past 12 months. The influenza vaccine was not included in UTD calculations for children who (1) presented between October and March and were <7 months old (ie, 6-month influenza vaccine age minimum + 1-month grace period) or (2) presented

between April and September and were <7 months old during the previous influenza season. According to WAIIS data, in 2016, 59% of children aged 19 to 35 months were UTD with the standard "4:3:1:3:3:1:4" Centers for Disease Control and Prevention–recommended immunization schedule; 27% of adolescents ≥13 years old were UTD with the Centers for Disease Control and Prevention–recommended 1:1:3 series.[27,28]

Additionally, we examined participants' WAIIS records to determine if they were due for vaccines at the time of presentation. Participants could be UTD but also due for vaccines. For example, participants who were 6 months and 2 weeks old may not have received their 6-month immunizations. Although these participants would be UTD because they are within the 30-day window in which to receive the 6-month vaccines, they also would be eligible to receive those vaccines. We evaluated WAIIS records to determine if participants who were due for vaccines on hospital admission had received any immunizations during their hospitalizations and within 30 days of discharge (ie, in their medical homes).

Covariates

Child age, sex, race and/or ethnicity, insurance, chronic disease status, and month of presentation were collected. A priori, we hypothesized that age and month of presentation may be related to UTD status because they influence the number of vaccine doses required to be UTD. The other demographic variables collected have been demonstrated to be related to parent-reported vaccine receipt.[12]

We categorized age into 4 groups: (1) 0 to 18 months, (2) 19 to 35 months, (3) 3 to 6 years, and (4) ≥7 years. These categories correspond to those used in WAIIS to evaluate immunization rates,[27] although we aggregated participants ≥7 years old because of the small sample size. Chronic disease status was determined by using the Pediatric Medical Complexity Algorithm (PMCA), which classifies children into 3 categories by using hospital discharge administrative billing codes: (1) no chronic disease, (2) noncomplex chronic disease, and (3) complex chronic disease.[29] Chart review was performed for all participants with a complex chronic disease to ensure that they met eligibility criteria. Month of presentation was categorized into influenza season (October–March) and noninfluenza season (April–September).[30]

Statistical Analysis

Descriptive statistics were used to describe the cohort of participants. We calculated the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of a child's provider-documented versus WAIIS UTD status. Sensitivity (true-positive rate) was calculated as the proportion of children who were documented as UTD by a provider among those who were UTD by using WAIIS. Specificity (true-negative rate) was calculated as the proportion of children who were documented by a provider as non-UTD among those who were non-UTD by using WAIIS. The PPV was estimated as the proportion of participants who were UTD by using WAIIS among those who were documented as UTD by providers. The NPV was estimated as the proportion of participants who were non-UTD by using WAIIS among those who were documented as non-UTD by providers. We estimated these statistics for the total sample and in subgroups defined by each covariate. We compared these measures across covariate groups using Fisher's exact test. We calculated 95% confidence intervals (CIs) using a binomial distribution.

We examined the relationship between covariates and UTD status (provider-documented and the WAIIS) using the χ^2 test of independence and bivariate logistic regression models to estimate odds ratios (ORs) and 95% CIs.

Using WAIIS data, we examined all immunizations given during hospitalization and within 30 days of discharge. We examined the relationship between covariates and vaccine receipt during and after hospitalization among those who were due for vaccines at hospital admission using bivariate logistic regression models. We used multivariable logistic regression models to examine the odds of receiving immunizations during or after hospitalization on the basis of (1) provider-documented UTD status or (2) WAIIS UTD status. Covariates were included in the multivariate models if they were significantly associated ($P < .10$) with either provider-documented or WAIIS UTD status (age, PMCA, season, and race and/or ethnicity).

Sensitivity Analysis

Because influenza vaccination is related to the admission season, we conducted a sensitivity analysis examining UTD status for all vaccines, excluding influenza. We

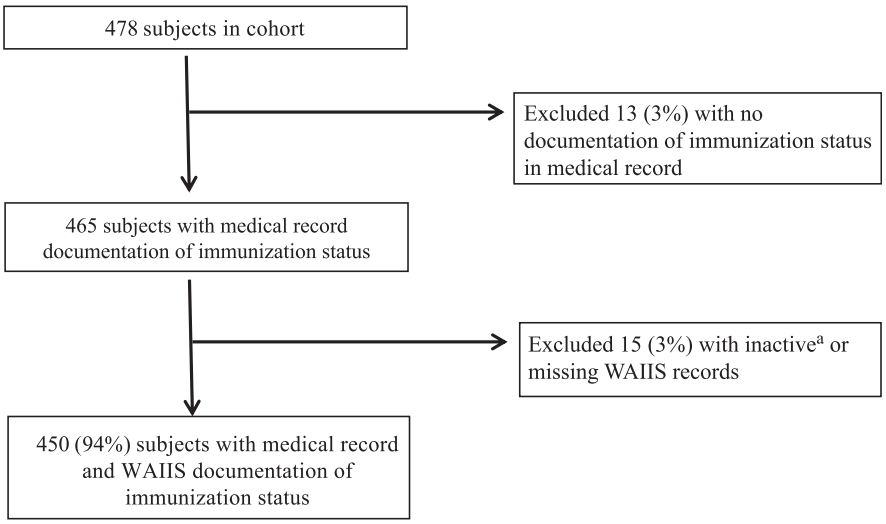

FIGURE 1 Study population and exclusion criteria. [a] Records can be marked as inactive by providers if a child moves out of state or is deceased.

TABLE 1 Unadjusted Analysis of Factors Associated With UTD Status per Provider Documentation and WAIIS

	All Subjects (n = 450), n (%)	Provider Documentation			WAIIS		
		UTD (n = 415), n (%)	Not UTD (n = 35), n (%)	OR (95% CI)	UTD (n = 188), n (%)	Not UTD (n = 262), n (%)	OR (95% CI)
Age*							
0–18 mo	185 (41)	169 (91)	16 (9)	Reference	114 (62)	71 (38)	Reference
19–35 mo	84 (19)	76 (90)	8 (10)	0.9 (0.4–2.2)	28 (33)	56 (67)	0.3 (0.2–0.5)*
3–6 y	117 (26)	108 (92)	9 (8)	1.1 (0.5–2.7)	33 (28)	84 (72)	0.2 (0.1–0.4)*
≥7 y	64 (14)	62 (97)	2 (3)	2.9 (0.7–13.1)	13 (20)	51 (80)	0.2 (0.1–0.3)*
Sex							
Girls	162 (36)	153 (94)	9 (6)	Reference	72 (44)	90 (56)	Reference
Boys	288 (64)	262 (91)	26 (9)	0.6 (0.3–1.3)	116 (40)	172 (60)	0.8 (0.6–1.2)
Race and/or ethnicity*							
White	232 (52)	205 (88)	27 (12)	Reference	92 (40)	140 (60)	Reference
Black or African American	35 (8)	35 (100)	0 (0)	—	19 (54)	16 (46)	1.8 (0.9–3.7)
Asian American	43 (10)	40 (93)	3 (7)	1.8 (0.5–6.1)	24 (56)	19 (44)	1.9 (1.0–3.7)
Latino or Hispanic	85 (19)	83 (98)	2 (2)	5.5 (1.3–23.5)*	34 (40)	51 (60)	1.0 (0.6–1.7)
Other	55 (12)	52 (95)	3 (5)	2.3 (0.7–7.8)	19 (35)	36 (65)	0.8 (0.4–1.5)
Insurance							
Private	270 (60)	252 (93)	18 (7)	Reference	116 (43)	154 (57)	Reference
Public	180 (40)	163 (91)	17 (9)	0.7 (0.3–1.4)	72 (40)	108 (60)	0.9 (0.6–1.3)
PMCA[a]**							
Nonchronic	376 (84)	344 (91)	32 (9)	Reference	165 (44)	211 (56)	Reference
Noncomplex chronic	66 (15)	63 (95)	3 (5)	2.0 (0.6–6.6)	19 (29)	47 (71)	0.5 (0.3–0.9)**
Complex chronic	8 (2)	8 (100)	0 (0)	—	4 (50)	4 (50)	1.3 (0.3–5.2)
Seasonality*							
April–September	129 (29)	122 (95)	7 (5)	Reference	43 (33)	86 (67)	Reference
October–March	321 (71)	293 (91)	28 (9)	0.6 (0.3–1.4)	145 (45)	176 (54)	1.6 (1.1–2.5)*

Percentages may not add to 100% because of rounding. —, When cells had 0 values, OR could not be calculated.
[a] See Simon et al.[29]
* $P < .05$; ** $P < .10$.

examined the relationship between UTD status, excluding influenza, with the covariates described above and calculated the sensitivity, specificity, PPV, and NPV for provider documentation compared with WAIIS records.

RESULTS

There were 478 participants who were hospitalized with a respiratory illness during the study period. Thirteen participants were excluded for not having documentation of immunization status; 15 were excluded because of inactive or missing WAIIS records (Fig 1). We included 450 participants. The median age was 2.1 years (interquartile range [IQR]: 0.75–4.9). Of the sample, 64% was of male sex, 52% was white, and 60% had private insurance (Table 1).

By provider documentation, 92% (n = 415) of participants were UTD at hospital admission. A higher proportion of children of color were UTD by provider documentation (Table 1). There were no other demographic differences in children who were UTD versus not UTD by provider documentation.

By WAIIS records, 42% (n = 188) of participants were UTD. Children >18 months old were significantly less likely to be UTD than children 0 to 18 months old. Participants had higher odds of being UTD during influenza season than during noninfluenza season (OR 1.6 [95% CI: 1.1–2.5]; $P < .05$; Table 1). When influenza

TABLE 2 Comparison of Immunization Status by Provider Documentation and WAIIS, Including Influenza Vaccine in UTD Status

	WAIIS		Total
	UTD, n (%)	Not UTD, n (%)	
Provider documentation			
UTD	185 (41)	230 (51)	415 (92)
Not UTD	3 (1)	32 (7)	35 (8)
Total	188 (42)	262 (58)	450 (100)

Percentages may not add to 100% because of rounding.

TABLE 3 Comparison of Immunization Status by Provider Documentation and WAIIS, Excluding Influenza Vaccine in UTD Status

	WAIIS		Total
	UTD, *n* (%)	Not UTD, *n* (%)	
Provider documentation			
UTD	237 (53)	178 (40)	415 (92)
Not UTD	4 (1)	31 (7)	35 (8)
Total	241 (53)	209 (46)	450 (100)

Percentages may not add to 100% because of rounding.

vaccines were excluded from UTD status, our results were unchanged (Supplemental Table 7).

Provider-documented immunization status was correct for 48% of participants (Tables 2 and 3). The sensitivity of provider documentation was high (98.4%; 95% CI: 95.4–99.7), but specificity was low (12.2%; 95% CI: 8.5–16.8). The PPV of provider-documented UTD status was 44.6% (95% CI: 39.7–49.5). The NPV was 91.4% (95% CI: 76.9–98.2; Table 4). The PPV was significantly lower for older children compared with children 0 to 18 months old ($P < .001$) and was significantly lower during noninfluenza season ($P < .05$). The specificity varied by race and/or ethnicity ($P < .05$; Table 4). The PPV of provider-documented UTD status was significantly higher when the influenza vaccine was excluded (influenza-excluded PPV 57.1 [95% CI: 52.2–61.9] versus influenza-included PPV 44.6 [95% CI: 39.7–49.5]; $P < .001$). There were no differences in sensitivity, specificity, or NPV when the influenza vaccine was excluded (Supplemental Table 8).

Fifty-seven percent of the sample ($n = 256$) was due for vaccines at hospital admission. Fifty-one participants (11% of the total sample) received a vaccine during their hospitalizations (2 received hepatitis B vaccine and 49 received the influenza vaccine). Children ≥7 years old had higher odds of receiving a vaccine than those ≤18 months old (OR 4.6 [95% CI: 1.9–11.4]; $P < .05$; Table 5). Of children with vaccines that were due at hospital admission, 44% ($n = 113$) received a

TABLE 4 Sensitivity and Specificity of Provider Documentation Versus WAIIS for UTD Immunization Status

Covariate	*n*	Sensitivity, % (95% CI)	Specificity, % (95% CI)	PPV, % (95% CI)	NPV, % (95% CI)
Age					
0–18 mo	185	97.4 (92.5–99.5)	18.3 (10.1–29.3)**	65.7 (58.0, 72.8)*	81.3 (54.4–96.0)
19–35 mo	84	100 (87.7–100)	14.3 (6.4–26.2)**	36.8 (26.1, 48.7)*	100 (63.1–100)
3–6 y	117	100 (89.4–100)	10.7 (5.0–19.4)**	30.6 (22.1, 40.2)*	100 (66.4–100)
≥7 y	64	100 (75.3–100)	3.9 (0.5–13.5)**	21.0 (11.7, 33.2)*	100 (15.8–100)
Sex					
Boys	162	98.3 (93.9–99.8)	14.0 (9.2–20.0)	43.5 (37.4, 49.8)	92.3 (74.9–99.1)
Girls	288	98.6 (92.5–100)	8.9 (3.9–16.8)	46.4 (38.3, 54.6)	88.9 (51.8–99.7)
Race and/or ethnicity					
White	232	97.8 (92.4–99.7)	17.9 (11.9–25.2)*	43.9 (37.0–51.0)	92.6 (75.7–99.1)
Black or African American	35	100 (82.4–100)	0 (0–20.6)*	54.3 (36.6–71.2)	—
Asian American	43	95.8 (78.9–99.9)	10.5 (1.3–33.1)*	57.5 (40.9–73.0)	66.7 (9.4–99.2)
Latino or Hispanic	85	100 (89.7–100)	3.9 (0.5–13.5)*	41.0 (30.3–52.3)	100 (15.8–100)
Other	55	100 (82.4–100)	8.3 (1.8–22.5)*	36.5 (23.6–51.0)	100 (29.2–100)
Insurance					
Private	270	99.1 (95.3–100)	11.0 (6.6–17.1)	45.6 (39.4–52.0)	94.4 (72.7–99.9)
Public	180	97.2 (90.3–99.7)	13.9 (8.0–21.9)	42.9 (35.2–50.9)	88.2 (63.6–98.5)
PMCA[a]					
Nonchronic	376	98.2 (94.8–99.6)	13.7 (9.4–19.1)	47.1 (41.7–52.5)	90.6 (75.0–98.0)
Noncomplex chronic	66	100 (82.4–100)	6.4 (1.3–17.5)	30.2 (19.2–43.0)	100 (29.2–100)
Complex chronic	8	100 (39.8–100)	0 (0–60.2)	50.0 (15.7–84.3)	—
Seasonality					
April–September	129	100 (91.8–100)	8.1 (3.3–16.1)	35.2 (26.8–44.4)*	100 (59.0–100)
October–March	321	97.9 (94.1–99.6)	14.2 (9.4–20.3)	48.5 (42.6–54.3)*	89.3 (71.8–97.7)
Total	450	98.4 (95.4–99.7)	12.2 (8.5–16.8)	44.6 (39.7–49.5)	91.4 (76.9–98.2)

UTD status includes influenza vaccine. —, not applicable.
[a] See Simon et al.[29]
* $P < .05$; ** $P < .10$.

TABLE 5 Unadjusted Analysis of Demographics for Subjects Who Are Due for Vaccines at the Time of Presentation Determined by Using WAIIS Records: Receipt of Vaccines During Hospitalization

	All Subjects (n = 256), n (%)	Received No Vaccines (n = 206), n (%)	Received ≥1 Vaccine (n = 50),[a] n (%)	OR (95% CI)
Age*				
0–18 mo	99 (39)	87 (88)	12 (12)	Reference
19–35 mo	52 (20)	42 (81)	10 (19)	1.7 (0.7–4.3)
3–6 y	69 (27)	55 (80)	14 (20)	1.8 (0.8–4.3)
≥7 y	36 (14)	22 (61)	14 (39)	4.6 (1.9–11.4)
Sex				
Girls	90 (35)	72 (80)	18 (20)	Reference
Boys	166 (65)	134 (81)	32 (19)	1.0 (0.5–1.8)
Race and/or ethnicity				
White	133 (52)	110 (83)	23 (17)	Reference
Black or African American	22 (9)	16 (73)	6 (27)	1.8 (0.6–5.1)
Asian American	15 (6)	10 (67)	5 (33)	2.4 (0.7–7.7)
Latino or Hispanic	53 (21)	40 (75)	13 (25)	1.6 (0.7–3.4)
Other	33 (13)	30 (91)	3 (9)	0.5 (0.1–1.7)
Insurance				
Private	145 (57)	117 (81)	28 (19)	Reference
Public	111 (43)	89 (80)	22 (20)	1.0 (0.6–1.9)
PMCA[b]				
Nonchronic	215 (84)	172 (80)	43 (20)	Reference
Noncomplex chronic	38 (15)	32 (84)	6 (16)	0.8 (0.3–1.9)
Complex chronic	3 (1)	2 (67)	1 (33)	2.0 (0.2–22.6)
Seasonality*				
April–September	54 (21)	51 (94)	3 (6)	Reference
October–March	202 (79)	155 (77)	47 (23)	5.2 (1.5–17.3)

[a] Fifty participants received immunizations. However, 1 received an influenza vaccine outside of influenza season and thus was not considered to be due for vaccines and not included in the above table.
[b] See Simon et al.[29]
* $P < .05$.

vaccine within 1 month of discharge (Table 6).

For children who were due for vaccines, there was no difference in the odds of receiving vaccines during hospitalization (adjusted OR [aOR] 0.8 [95% CI: 0.3–2.5]; $P = .74$) or after discharge (aOR 1.3 [95% CI: 0.6–2.9]; $P = .47$) by provider-documented UTD status. Children who were not UTD (versus UTD) by WAIIS status had no difference in the odds of receiving immunizations within 1 month of discharge (aOR 1.1 [95% CI: 0.5–2.3]; $P = .24$). This result was unchanged when the influenza vaccine was excluded (aOR 1.5 [95% CI: 0.8–2.8]: $P = .17$).

DISCUSSION

Provider-documented immunization status at the time of hospital admission for children with respiratory illnesses is inaccurate more than half of the time when compared with a child's immunization status in WAIIS. This suggests that inpatient providers predominately rely on parent report for assessing a child's immunization status. With this finding, we support the need to integrate state immunization registries into the point of care in hospital settings.

The sensitivity of provider-documented immunization status was high, meaning it was rare for providers to document a child as not being UTD who was truly UTD. However, the low specificity of provider-documented UTD status illustrates that provider documentation yields many false-positives (ie, children are reported to be UTD but are not).

Researchers in most previous studies in which the correlation between parent report and immunization records is examined have approached parents to specifically ask about their children's immunization status.[6,11–15] We used medical record abstraction of provider-documented immunization status because it accounts for what a provider knew about a child's immunization status at the time of hospitalization. We identified high rates (97.3%) of provider-documented immunization status in our study population. Additionally, we were able to match nearly all participants (96.8%) with an active record in WAIIS. Our results of high sensitivity and low PPV are similar to those in other studies of parent-reported immunization status in acute care settings.[6,11] With this finding, we support our hypothesis that provider-documented immunization status is likely based on parent report.

TABLE 6 Unadjusted Analysis of Demographics for Subjects Who Are Due for Vaccines at the Time of Presentation Determined by Using WAIIS Records: Receipt of Vaccines Within 1 Month of Discharge

	All Subjects (n = 256), n (%)	Received No Vaccines Postdischarge (n = 143), n (%)	Received ≥1 Vaccine Postdischarge (n = 113), n (%)	OR (95% CI)
Age*				
0–18 mo	99 (39)	51 (52)	48 (48)	Reference
19–35 mo	52 (20)	23 (44)	29 (56)	1.3 (0.7–2.6)
3–6 y	69 (27)	46 (67)	23 (33)	0.5 (0.3–1.0)
≥7 y	36 (14)	23 (64)	13 (36)	0.6 (0.3–1.3)
Sex*				
Girls	90 (35)	41 (46)	49 (54)	Reference
Boys	166 (65)	102 (61)	64 (39)	0.5 (0.3–0.9)
Race and/or ethnicity				
White	133 (52)	80 (60)	53 (40)	Reference
Black or African American	22 (9)	16 (73)	6 (27)	0.6 (0.3–1.5)
Asian American	15 (6)	7 (47)	8 (53)	1.7 (0.6–5.0)
Latino or Hispanic	53 (21)	24 (45)	29 (55)	1.8 (1.0–3.5)
Other	33 (13)	16 (48)	17 (52)	1.6 (0.7–3.4)
Insurance				
Private	145 (57)	77 (53)	68 (47)	Reference
Public	111 (43)	66 (59)	45 (41)	0.8 (0.4–1.3)
PMCA[a]				
Nonchronic	215 (84)	115 (53)	100 (47)	Reference
Noncomplex chronic	38 (15)	26 (68)	12 (32)	0.5 (0.3–1.1)
Complex chronic	3 (1)	2 (67)	1 (33)	0.6 (0.1–6.4)
Seasonality				
April–September	54 (21)	30 (56)	24 (44)	Reference
October–March	202 (79)	113 (56)	89 (44)	1.0 (0.5–1.8)

[a] See Simon et al.[29]
* $P < .05$.

Participants were more likely to be UTD according to WAIIS records during influenza season. The reason for this is unclear; perhaps providers are more likely to critically evaluate children's immunization status during influenza season and catch them up if not UTD. Children may have more visits with their primary care providers during influenza season, providing more opportunities to vaccinate. We found that nearly all of the vaccines administered during hospitalization were influenza vaccines, suggesting a benefit from the system at the study hospital of providing influenza vaccines when children are not UTD.[31]

Lastly, there were low rates of catch-up immunizations posthospitalization. It appears from our observational study that posthospitalization follow-up visits with a child's primary care provider are not being used to catch up on immunizations for children who are underimmunized. We identified no difference in vaccines given within 1 month of discharge for children who are not UTD versus those who are UTD either by provider documentation or WAIIS records. Few studies have been focused on hospitalization and postdischarge visits as an opportunity for immunization, nor have researchers explored the barriers contributing to such missed opportunities for catch-up immunizations.[21,22,32] Small studies have revealed promise in engaging families at the time of hospitalization to promote catch-up immunizations, although the lack of integration of IISs has made gathering accurate immunization records resource intensive.[21,22] Although a better integration of IISs and EMRs would improve the identification of children who are not UTD at the time of hospitalization, the recognition of underimmunization status may not be enough to promote catch-up immunizations postdischarge. There is likely a need for better communication between acute and primary care settings regarding vaccines and the evaluation of this critical time frame as an opportunity to promote catch-up immunizations in this high-risk population.

In our study, WAIIS data were used as the gold standard for determining UTD immunization status. A previous Canadian study revealed that 11% of children were misclassified as not being UTD by registry data when they were UTD.[33] Additionally, participants may have incomplete registry data if their vaccines were incorrectly entered into WAIIS, if they moved in and out of Washington state, or if their primary care providers do not participate in WAIIS.[34] We tried to limit this by only including

participants who were treated in Washington and had an active WAIIS profile. Without getting immunization records from all sources, we are unable to further confirm immunization status. This misclassification may also contribute to the low rates of catch-up immunizations posthospitalization if a child was truly UTD at the time of hospitalization.

The completeness of WAIIS also deserves mention because our estimates of UTD status using WAIIS are lower than estimates from the National Immunization Survey (NIS), in which researchers report that 75.7% (SD 5.8) of children 19 to 35 months old were UTD for 2016 compared with our study, with 49% being UTD when excluding the influenza vaccine (Supplemental Table 7).[35] There are differences in sampling mechanisms between the NIS and WAIIS, with the NIS relying on adequate provider-reported vaccination records.[36] Also, the population we sampled of children admitted to the hospital may not be representative of all children sampled in the NIS. These children may be less likely to be UTD on vaccines, which may account for some of the difference in our estimate.[5,37]

We hypothesize that the inaccuracy of provider-documented UTD status is due to providers relying on parent-reported immunization status. It is possible that providers used WAIIS to verify a child's immunization status, which could bias our findings. Providers may also document a child's immunization status without relying on parent report or WAIIS. EMR documentation prompts may lead to a premature completion of this field without confirming the child's immunization status with the caregiver. In fact, EMR prompts may lead to inaccurate UTD status documentation because prompts that encourage providers to ask the question, "Is your child UTD on immunizations?" may yield a "yes" answer more often than prompts encouraging the question, "Are there any vaccines your child has not yet received?"

This study was done at a single institution with an IIS that was previously validated for research.[24] The majority of providers were pediatric trained and may have a heightened awareness of the importance of immunizations. Nationally, there is variation in the availability and accuracy of immunization state registries.[8] Thus, findings may not be representative of other health care settings.

CONCLUSIONS

Provider-documented UTD immunization status for children with acute respiratory illnesses at hospital admission is often inaccurate. The integration of statewide immunization registries and hospital-based information technology would help inpatient providers identify underimmunized children in real time. Follow-up visits after hospitalization are being underused as a method to provide immunizations to children who are not UTD.

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