RESEARCH ARTICLE

Pediatric Hospitalizations: Are We Missing an Opportunity to Immunize?

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ABSTRACT

OBJECTIVES: Fewer than half of children receive all recommended immunizations on time. Hospitalizations may be opportunities to address delayed immunizations. Our objectives were to assess (1) prevalence of delayed immunizations among hospitalized patients, (2) missed opportunities to administer delayed immunizations, and (3) time to catch up after discharge.

METHODS: We conducted a retrospective cohort study investigating immunization status of patients 0 to 21 years of age admitted to an academic children's center from 2012 to 2013 at the time of admission, at discharge, and 18 months postdischarge. Immunization catch-up at 18 months postdischarge was defined as having received immunizations due on discharge per Centers for Disease Control and Prevention recommendations. χ^2 and t test analyses compared characteristics among patients caught up and not caught up at 18 months postdischarge. Analysis of variance and logistic regression analyses compared mean number of immunizations needed and odds of immunization catch-up among age groups. Kaplan-Meier and Cox proportional hazards analyses compared catch-up time by age, race, sex, and insurance.

RESULTS: Among 166 hospitalized patients, 80 were not up to date on immunizations at admission, and only 1 received catch-up immunizations before discharge. Ninety-nine percent (79 of 80) were not up to date on discharge per Centers for Disease Control and Prevention recommendations. Thirty percent (24 of 79), mostly adolescents, were not caught up at 18 months postdischarge. Median postdischarge catch-up time was 3.5 months (range: 0.03–18.0 months). Patients 0 to 35 months of age were more likely to catch up compared with those of other ages (hazard ratio = 2.73; $P = .001$), with no differences seen when comparing race, sex, or insurance.

CONCLUSIONS: Pediatric hospitalizations provide important opportunities to screen and immunize children.

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Immunizations are 1 of the most valuable pediatric preventive services; however, fewer than half of children receive all recommended immunizations on time.[1–5] In the United States, only 70% of children have completed their primary immunization series, which varies by race and poverty level.[5] Immunization delivery at locations outside of the primary care clinic, such as pharmacies, schools, and emergency departments, has been studied and proposed.[6,7] With almost 5.9 million pediatric hospital stays per year in the United States, hospitalizations represent potential opportunities to improve immunization rates for children with delayed immunizations.[6,8–12]

Among hospitalized children in the United States, up to 50% are "not current" on immunizations, and <30% have received any catch-up immunizations during their hospitalization.[10,12,13] Few studies have explored pediatric hospitalizations as an opportunity to immunize patients, and they focus primarily on preschool-aged children. There are gaps in our understanding of immunization needs among hospitalized patients and immunization practice patterns postdischarge.[8,12,14–16] We aim to address these gaps in the literature. Our objectives were to assess the prevalence and characteristics of delayed immunizations among hospitalized patients, identify what proportion of study patients had a missed immunization opportunity during hospitalization, and evaluate the time to catch-up within 18 months after hospital discharge for immunizations needed at the time of hospital discharge.

METHODS

Study Design, Setting, and Patient Population

We performed a retrospective cohort study investigating the immunization status of patients who were admitted to an urban tertiary-care children's center from May 23, 2012, to May 22, 2013. We included admitted patients 0 to 21 years of age who were affiliated with the hospital-based pediatric primary care clinic to ensure access to complete and accurate outpatient immunization records. Included patients had at least 1 clinic visit within 2 years before hospitalization to capture active patients receiving primary care. The hospital-based clinic serves ∼8000 children annually from birth through adolescence; the majority of patients are African American and insured through Medicaid. Patients were excluded if they were admitted to the PICU because of higher-level acuity and greater potential for contraindication to immunization. For patients with multiple hospitalizations, we only included data from the last hospitalization to capture the latest immunization data.

Immunization status was assessed at 3 time points (hospital admission, discharge, and 18 months postdischarge) by using outpatient electronic health record (EHR) data and manual review of inpatient records. Patients who were not up to date (UTD) on immunizations, as determined by immunization type and number of doses needed at time of discharge, were managed for a total of 18 months postdischarge to determine if the immunizations needed had been obtained. This study was approved by the Johns Hopkins University Institutional Review Board. During the time of the study, the inpatient and outpatient settings used different EHR systems, and neither alerted clinicians to patients with delayed immunizations. There were no initiatives or policies targeting inpatient immunization practices or promoting vaccination after discharge. However, it was standard practice to schedule a postdischarge follow-up appointment with the primary care provider (PCP) within 2 days of discharge. In the outpatient setting, it was standard practice for providers to review the Maryland Immunization Information System (ImmuNet) to update clinic immunization records manually during well-child visits to capture any immunizations administered outside of Johns Hopkins. Maryland ImmuNet is a secure, statewide database storing immunization records, which are entered and accessed by health care providers, pharmacies, and schools through a Web-based portal.[17]

Outcome Measures: Immunization Status and Time to Catch-up

Immunization status was defined by applying the 2012 Centers for Disease Control and Prevention (CDC), American Academy of Pediatrics, and Advisory Committee on Immunization Practices guidelines.[18] Following the schedule and timing of the 2012 CDC recommendations, the immunizations included in this study were the following: rotavirus; inactivated polio vaccine (IPV); hepatitis A (HepA); hepatitis B (HepB); diphtheria-tetanus-acellular pertussis (DTaP); tetanus toxoid, reduced diphtheria toxoid, and acellular pertussis, adsorbed (Tdap); *Haemophilus influenzae* type B (HiB); pneumococcal conjugate vaccine (PCV); measles-mumps-rubella (MMR); varicella zoster vaccine (VZV); meningococcal conjugate vaccine (MCV); and human papillomavirus (HPV).[19]

We also determined immunization status by applying the 2012 State of Maryland–mandated school-entry immunization schedule, which did not mandate HPV, HepA, and rotavirus immunizations.[20] Influenza vaccination was excluded because of the seasonal variability in administration and the fact that not all patients would be offered the immunization within the study period.

Immunization catch-up status at 18 months postdischarge was defined as the receipt of all immunizations that were needed at the time of hospital discharge. If an immunization was due during the 18-month follow-up period but was not required at the time of discharge, it was not included in determining catch-up status at 18 months postdischarge. Time to catch-up was defined as the elapsed time in months from hospital discharge to receipt of all immunizations needed at the time of discharge.

Variables

Patient characteristics were obtained from medical record review and included age, sex, race, presence of a complex chronic condition (CCC), type of insurance, and frequency of clinic visits during the follow-up period. A CCC was defined by previously published diagnostic codes and obtained by medical record review of problem lists and clinical documentation.[21]

Patients were stratified into 3 age categories: 0 to 35 months of age, 3 to 10 years of age, and >11 years of age. This age stratification was chosen on the basis

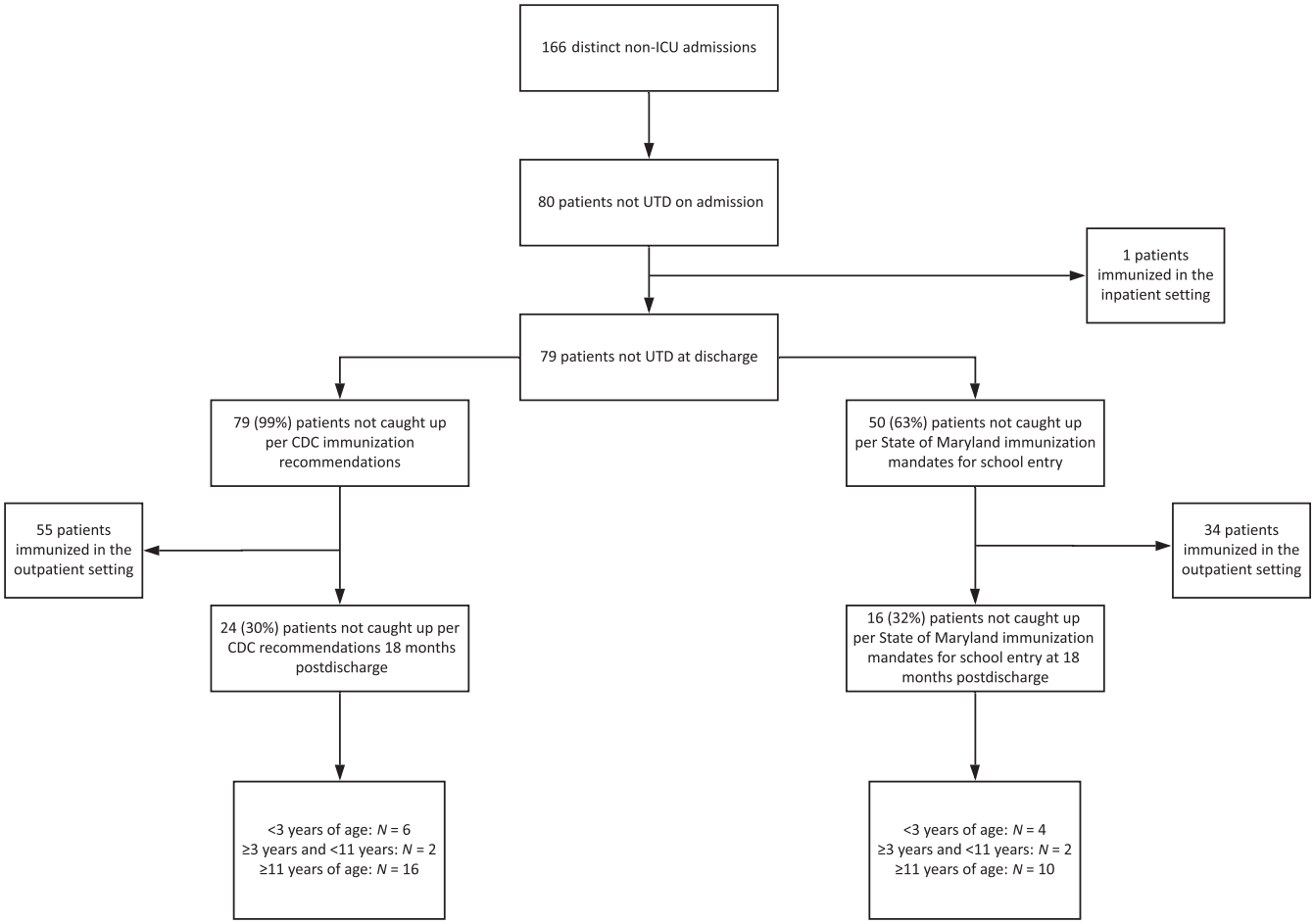

FIGURE 1 Immunization status at hospital discharge and 18 months postdischarge per CDC recommendations and State of Maryland mandates for school entry. At the time of this study, the State of Maryland immunization mandates for school entry included all CDC immunizations except HepA, HPV, and rotavirus.

of literature suggesting that children of lower income levels and minority children were less likely to have completed vaccinations by age 36 months.[22] Because of our small sample size, we combined the following ages into 1 category of 3 to 10 years of age. Finally, the age category of ≥11 years correlates with adolescent immunization schedules.

Data Collection

To determine patient immunization status at the time of hospital admission, a validated, computerized decision-support algorithm, adapted from 2012 CDC immunization recommendations, was applied to the outpatient EHR.[18] Retrospective manual review of inpatient hospital records was performed to identify immunizations given during hospitalization. For patients not UTD on hospital discharge, outpatient immunization records were reviewed up to 18 months postdischarge to determine if immunizations needed at discharge were given in the outpatient setting. For patients who did not receive needed immunizations during the postdischarge follow-up period, we reviewed clinical encounter documentation to identify potential reasons for failure to immunize, such as medical contraindication or parental deferral.

Analysis

Means, SDs, and frequencies were calculated to summarize measures of central tendency and dispersion for demographics and immunization status. We compared characteristics of patients, who were caught up versus not caught up at 18 months postdischarge, using χ^2 tests for categorical variables and 2-sided t tests for mean age. Analysis of variance was performed to determine differences in the mean number of immunizations needed to achieve catch-up status. Logistic regression analysis was performed to determine the odds of catching up on immunizations by comparing various age groups. Overall catch-up time was evaluated by using the Kaplan-Meier curve. Cox proportional hazards models were used to determine the effect of age group, race, sex, and insurance type on time to complete immunizations. Analyses were performed by using Stata 14.2 (Stata Corps, College Station, TX). $P < .05$ was considered statistically significant.

RESULTS

Among 166 eligible patients from distinct admissions, 80 (48%) were not UTD on

immunizations at time of admission per CDC recommendations, and only 1 2-month-old patient received catch-up immunizations before discharge. Therefore, 99% ($n = 79$) did not receive immunizations during the course of hospitalization and were not caught up per CDC recommendations, whereas 63% ($n = 50$) were not caught up per State of Maryland–mandated school-entry requirements (Fig 1).

Overall, among those patients not UTD on hospital discharge, the mean age was 7.6 years, and 42% were girls (Table 1). The majority were African American and received public insurance. Among patients who caught up with immunizations at 18 months postdischarge, the mean age was 6 years compared with an older mean age of 11 years for patients not caught up at 18 months ($P < .01$). The majority of children caught up at 18 months were in the youngest age category of 0 to 35 months, whereas the majority of those not caught up at 18 months were ≥11 years ($P = .04$). There were no statistically significant differences between the groups when comparing sex, race, insurance type, or presence of a CCC. The odds of catching up on immunization at 18 months postdischarge for patients ≥11 years of age was 0.23 (95% confidence interval [CI]: 0.07–0.74; $P = .01$) times the odds as those for patients 0 to 35 months of age. There were no differences in odds of catch-up when comparing patients 3 to 10 years with those 0 to 35 months (odds ratio 0.49; 95% CI: 0.10–2.55; $P = .40$) or patients 3 to 10 years to ≥11 years (odds ratio 0.47; 95% CI: 0.11–2.08; $P = .32$).

Immunizations Needed at Time of Hospital Discharge

At the time of discharge, 79 patients needed 203 immunizations doses to be UTD per CDC recommendations. Patients <3 years ($n = 32$) and ≥11 years of age ($n = 34$) were in greatest need of immunizations, accounting for 84% (66 of 79) of patients not UTD. This distribution was greater than in the clinic population that was hospitalized during that time, in which patients <3 and ≥11 years of age accounted for 66% (110 of 166) of eligible patients admitted to the hospital during the study period. The mean number of immunization doses needed by age category was as follows: 0 to 35 months, 4.6 (SD 3.1; $N = 32$); 3 to 10 years, 5.9 (SD 4.1; $N = 11$); and ≥11 years, 2.5 (SD 2.8; $N = 36$). There were statistically significant differences between mean numbers of immunization doses needed in patients 0 to 35 months of age versus those ≥11 years of age ($P = .02$) and in patients 3 to 10 years of age versus those ≥11 years of age ($P = .007$).

Nearly half (47%) the patients only needed 1 dose of 1 type of immunization, and 9% (7 of 79) only needed 2 types of immunizations (1 dose each) to catch up on immunizations needed at discharge. The most common types of immunizations needed at discharge included HPV, DTaP, and HepA (Fig 2). When excluding HepA, HPV, and rotavirus, which were not mandated for school entry in the State of Maryland, DTaP, IPV, and VZV were the most common immunization types needed on hospital discharge.

Immunization Follow-up 18 Months Postdischarge From the Hospital

Among patients who were not UTD per CDC recommendations on hospital discharge, 30% ($n = 24$) did not catch up during the 18 months postdischarge (Fig 1). Of the 24 patients who remained underimmunized, 19 were seen in a clinic, whereas 5 were not seen. HPV, HepA, MMR, and VZV were the most common immunization types not administered during the follow-up period (Fig 3). Among patients 0 to 35 months of age, DTaP, MMR, VZV, and IPV were the most common immunization types not administered. Among those ≥11 years, HPV was the most common immunization type not administered. Patients who did not catch up postdischarge had fewer clinic visits compared with patients who did catch up, especially in the 3- to 10-years-of-age category (Supplemental Table 2).

Per State of Maryland immunization mandates, 32% ($n = 16$) of patients remained underimmunized 18 months postdischarge (Fig 1). Of those not fully

TABLE 1 Demographics of Patients Not Caught- up on Immunizations per CDC Recommendations at Discharge and Caught-up Status 18 Months After Hospital Discharge

	Total Patients Not Caught up[a] at Hospital Discharge ($N = 79$), n (%)	Patients Caught up 18 mo Postdischarge ($N = 55$), n (%)	Patients Not Caught up 18 mo Postdischarge ($N = 24$), n (%)	P
Age, mean (SD)	7.6 (6.7)	5.9 (6.0)	11.3 (6.3)	<.01
Age category				
0–35 mo	32 (40)	27 (47)	5 (25)	.04
3–10 y	11 (16)	8 (16)	3 (17)	—
≥11 y	36 (43)	20 (36)	16 (58)	—
Sex (female)	33 (42)	25 (43)	8 (33)	.32
Race				
African American	70 (89)	49 (89)	21 (88)	.98
White	3 (4)	2 (4)	1 (4)	—
Other	6 (7)	4 (7)	2 (8)	—
Insurance type				
Public	68 (86)	49 (89)	19 (79)	.29
Private	10 (13)	5 (9)	5 (21)	—
Other	1 (2)	1 (2)	0 (0)	—
CCC				
Present	49 (62)	32 (58)	17 (71)	.29
Absent	30 (38)	23 (42)	7 (29)	—

—, not applicable.

[a] Caught up at 18 mo refers to the patient having received immunizations needed at the time of hospital discharge. Not caught up at 18 mo refers to the patient not having received immunizations needed at the time of hospital discharge.

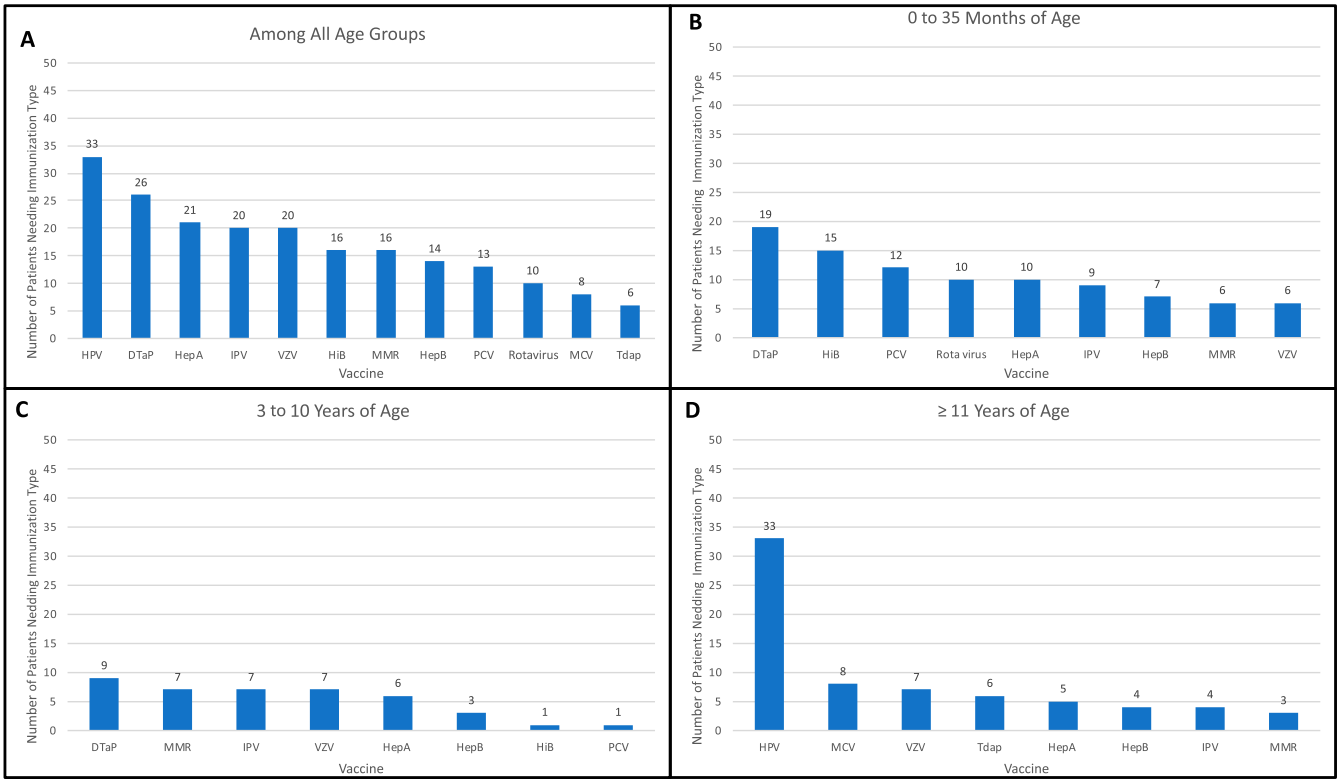

FIGURE 2 Type of immunization needed at hospital discharge, by age group, per CDC immunization recommendations. A, Among all age groups. HPV, DTaP, and HepA were the immunizations in greatest need. B, Patients 0 to 35 months of age. DTaP, HiB, and PCV were in greatest need. C, Patients 3 to 10 years of age. DTaP, MMR, IPV, and VZV were immunizations in greatest need. D, Patients ≥ 11 years of age. HPV, MCV, and VZV were in greatest need.

immunized, 13 had been seen in a clinic, whereas 3 were not seen within the follow-up period. The majority of those who remained underimmunized were adolescents with a mean of 3.4 clinic visits and a CCC, with the most prevalent chronic condition being sickle cell disease.

Reasons for Incomplete Immunization Catch-up

Among the 19 patients seen in a clinic who did not receive immunizations, 5 were seen exclusively for acute concerns, and immunization status was not routinely reviewed. Of the remaining 14 patients seen for well-child care, 5 refused immunizations, 1 did not obtain all immunizations needed for catch-up, and the remaining 8 did not have any clinical documentation regarding immunizations. Of note, 9 patients only needed 1 immunization for catch-up (5 HPV, 1 HepA, 2 HepB, and 1 VZV). Of note, among patients needing immunizations, there was no clinical documentation of medical contraindication to immunizations on chart review.

Time to Immunization Catch-up

Among those completing immunizations ($n = 55$), it took a median of 3.5 months (range: 0.03–18.0 months) from hospital discharge to catch up (Supplemental Fig 5). When comparing immunization status by age, patients 0 to 35 months were more likely to catch up compared with those in other age groups (hazard ratio [HR] = 2.73; $P = .001$; Fig 4). There were no differences in catch-up time when comparing groups on the basis of race (HR = 1.12; $P = .79$), sex (HR = 0.96; $P = .88$), or insurance type (HR = 0.93; $P = .88$).

DISCUSSION

Our study highlights the potential opportunity for catch-up on immunizations in the inpatient setting, with >50% of patients not being UTD on immunizations at hospital admission. Among the 80 hospitalized patients who were not UTD, only 1 patient received necessary immunizations during their hospitalization to achieve UTD status. Thus, there were 79 (of 80; 99%) missed patient opportunities to immunize during hospitalization. Among these patients, 30% remained underimmunized per CDC recommendations at 18 months postdischarge and 32% per State of Maryland–mandated immunizations. One-third of patients only needed 1 dose of 1 type of immunization for catch-up, which underscores the potential of the inpatient setting to treat these patients, especially adolescents. Among those who caught up on immunizations postdischarge, the mean time to catch up was 3.5 months, which could potentially be improved by using inpatient hospitalizations as an opportunity to administer delayed immunizations.

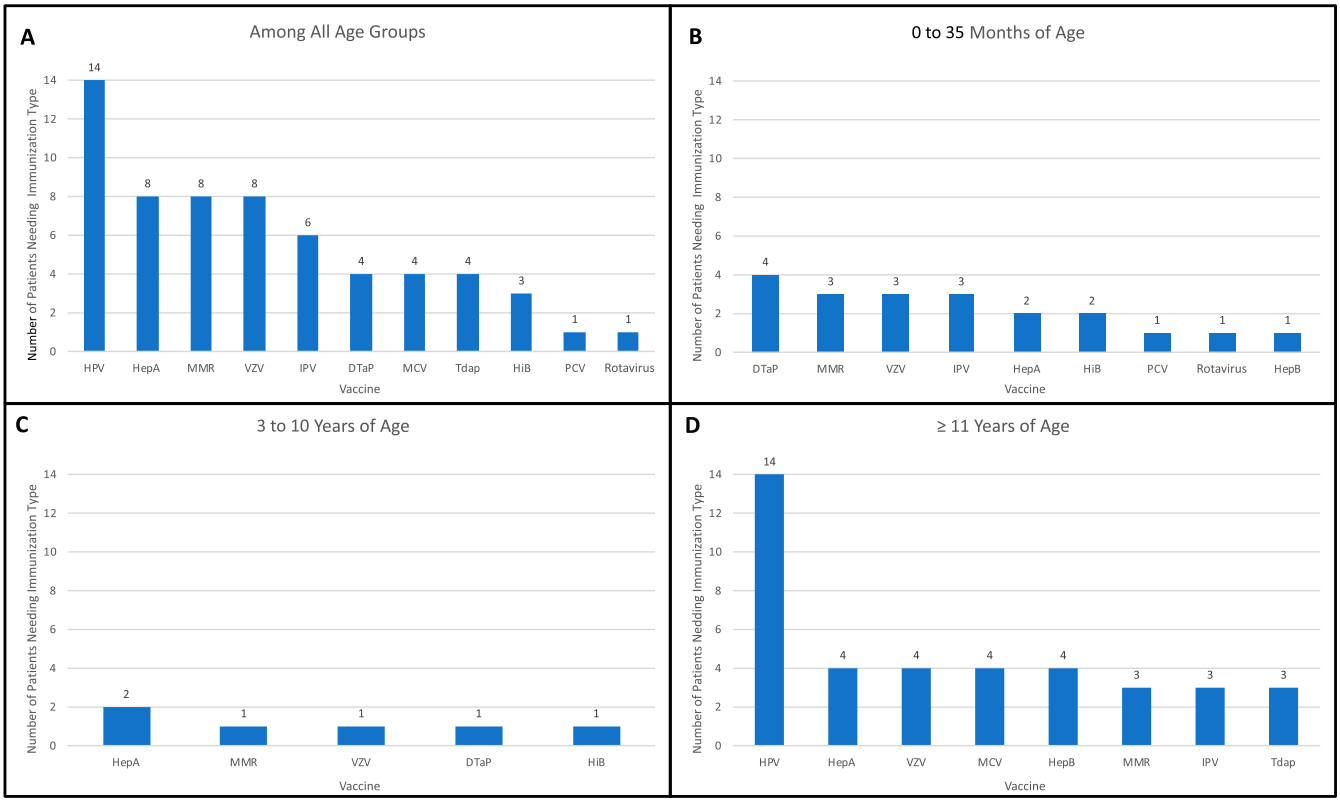

FIGURE 3 Type of immunizations still needed after the 18-month–postdischarge follow-up period, by age group, per CDC immunization recommendations. A, Among all age groups. HPV, HepA, MMR, and VZV were the most common immunizations not administered during follow-up. B, Patients 0 to 35 months of age. DTaP, MMR, VZV, and IPV the most common immunizations not administered during follow-up. C, Patients 3 to 10 years of age. Few immunizations had not been administered during follow-up, including HepA. D, Patients ≥11 years of age. HPV was the most common immunization not administered during follow-up.

Previously reported challenges to implementing and sustaining inpatient immunization practices include cost and willingness of insurance companies to pay for inpatient immunizations as well as cultural barriers and practice expectations of both hospitalists and PCPs.[11,12,15] Challenges with reimbursement may affect children who qualify for free vaccines that are distributed only through clinics via the CDC Vaccines for Children Program.[18] Although there have been efforts to expand opportunities to screen for immunization status, such as within school-based health clinics, barriers to accessing immunization records make this difficult to perform routinely outside of the primary care setting.[15,23,24]

Potential interventions to address these barriers will need to optimize communication, alignment, and collaboration between health care systems, hospitalists, and PCPs. A validated, computerized decision-support algorithm, similar to the 1 used in this study, could automatically screen a patient's immunization history on admission and alert providers of those not UTD. However, there would need to be improved access and integration of data from various sources and immunization registries. Additionally, future studies could evaluate the impact of inpatient immunization interventions on outpatient primary care delivery.[25]

Several studies have highlighted the importance of communication and collaboration between clinicians in inpatient and outpatient settings to ensure that children are fully immunized.[8–10,15,16] These studies have successfully increased inpatient pediatric immunization rates by accurately reviewing immunization records during hospitalization, effectively addressing parental concerns, and informing parents and PCPs about needed catch-up doses.[8,10,15] One pilot study demonstrated significant improvements in immunization rates from 73% on admission to 80% at a 1-month follow-up by using a dedicated coordinator.[15] Our study highlights the potential for inpatient hospitalizations to serve as opportunities for catching up on immunizations, although collaborative partnerships and communication between inpatient and outpatient clinicians would be needed.

Concordant with national trends, our study showed high numbers of adolescents with delayed immunization.[18,21,26] In our study, adolescents and children <3 years of age had the greatest need for immunizations at the time of hospital discharge. This finding remained true when excluding HPV, HepA, and rotavirus. Patients ≥11 years of age were in greatest need of HPV and MCV

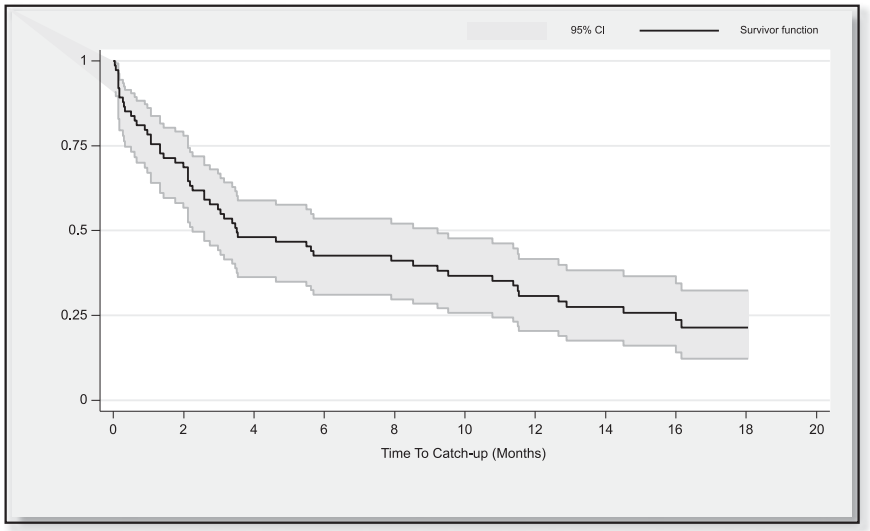

FIGURE 4 Cox proportional hazards models showing effects of age on time to catch up on immunizations per CDC recommendations. Patients 0 to 35 months of age were more likely to catch up on immunizations when compared with those of other age groups (HR = 2.73; $P = .001$).

immunizations, aligning with reports of teenagers struggling to meet Healthy People 2020 targets.[27,28] Studies have attributed the absence of a medical home as a major reason for adolescent underimmunization.[27,29] Hospitalizations may serve as opportunities to improve adolescent immunization rates. Children <3 years of age achieved the greatest catch-up (84%) among all groups in the study, and this is likely due to frequent well-child visits in this age group.

During the study period, the State of Maryland did not mandate all immunizations recommended by the CDC, including HPV, HepA, and rotavirus immunizations. State-mandated immunizations for school entry have been shown to improve immunization compliance.[30,31] Our study showed that HPV and HepA were 2 immunizations in greatest need among our cohort, which have potential for improved compliance with mandates for school entry.

Our study has several limitations. First, the records used to assess immunization status may not have been complete. It is possible that immunizations were administered in other health care settings, such as the Department of Health, that were not reflected in our medical records. However, at the hospital-based clinic, the state registry, ImmuNet, is reviewed during all well-child visits, and medical records are updated manually to reflect the most UTD immunization records available. Although ImmuNet was used to capture immunizations given in other settings, records may not have been complete. It is not mandatory for all providers to enter immunizations into ImmuNet, and it does not automatically capture immunizations given out of state. Additionally, during the study period, only 51% of children <6 years of age and 16.8% of adolescents 11 to 17 years participated in Maryland ImmuNet in 2012.[32] Also, this study was conducted at a single large, urban academic medical system; thus, observations may not be generalizable to other settings. Lastly, for patients who did not follow-up in the study clinic during the postdischarge follow-up period, it is possible that these patients changed medical homes and received immunizations in another health care setting.

CONCLUSIONS

Pediatric hospitalizations provide opportunities to identify and facilitate catch-up immunizations, especially for the adolescent population. Innovative approaches that integrate care across inpatient and outpatient settings are needed to improve immunization rates and provide the best preventive care for children.

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