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COVID-19 and Completion of Select Routine Childhood Vaccinations

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Abstract

OBJECTIVES: To evaluate rotavirus (RV), diphtheria, tetanus, and acellular pertussis (DTaP), and abstract pneumococcal conjugate vaccine (PCV) vaccine coverage and factors associated with vaccine uptake from 2018 through 2023.

METHODS: We included infants born between January 1, 2018 and May 31, 2023, with a minimum of 9 months of enrollment in the first 12 months of life and at least 1 medical visit between 9 and 12 months at 1 of 8 Vaccine Safety Datalink health systems. We evaluated coverage with 2 doses of RV, DTaP, and PCV vaccines at 5 months and completion of recommended doses by 12 months. We evaluated associations of patient race, ethnicity, caregiver's primary language, Medicaid, and time period with vaccine uptake.

RESULTS: We included 395 143 infants: 48.4% female; 14.7% non-Hispanic Asian; 5.8% non-Hispanic Black; 34.2% Hispanic; and 20.6% with Medicaid. Coverage for 2 doses of all 3 vaccines at 5 months was 87.8% (95% CI 86.9–88.7) in February 2020 vs 80.8% (95% CI 79.8–81.8) in October 2023. Vaccine series completion at 12 months was highest in January 2020 with 92.3% (95% CI 91.6–92.9) vs 89.6% (95% CI 88.8–90.3) in October 2023. Factors associated with lower vaccine uptake included having a caregiver whose primary language was not English or Spanish, non-Hispanic Black race, and Medicaid.

CONCLUSION: Over 3 years after the COVID-19 pandemic started, coverage for selected routine childhood immunizations remained below prepandemic levels. Demographic factors, which may reflect structural barriers to accessing care, likely affected coverage. Focused interventions are needed to improve vaccine coverage in all populations.

Video Abstract

INTRODUCTION

The COVID-19 pandemic disrupted health care delivery and resulted in reductions in vaccine administrations for all pediatric age groups.^{1–11} A previous Vaccine Safety Datalink (VSD) study identified decreases in weekly vaccine administrations across pediatric age groups during the first 6 months of the COVID-19 pandemic and decreases in the proportion of those up-to-date (UTD) for recommended vaccinations for infants reaching age 7 and 18 months during May 2020 and September 2020, compared with the same months in 2019.¹² Additional studies have shown similar decreases in vaccination during this time period.^{7,13} Differences in pediatric vaccine coverage based on race, ethnicity, and insurance are well documented with coverage lower among non-Hispanic Black individuals compared with other race and ethnic groups and those with Medicaid lower than those with private insurance both before and after the start of the COVID-19 pandemic.^{12,14–16} Less is known about the pandemic's impact on these disparities.

Three routine childhood immunizations recommended at ages 2, 4, and 6 months are rotavirus (RV), diphtheria, tetanus, acellular pertussis (DTaP), and the pneumococcal conjugate vaccine (PCV).¹⁷ Differences in coverage for these vaccines were present before the pandemic. According to the National Immunization Survey, RV vaccine series completion was 76% to 77% for children born between 2017 and 2020 in the United States.^{14,15} In contrast, receipt of 3 or more doses of the DTaP vaccine and PCV by age 24 months was greater than 90%.¹⁵ This difference may reflect the limited window of eligibility for RV vaccine series completion. The maximum age for first RV vaccine dose is 14 weeks and 6 days, and the maximum age for the final RV dose is 8 months and 0 days.¹⁸ This limited window of vaccine administration may have resulted in the COVID-19 pandemic disproportionately affecting RV vaccine coverage compared with other routine childhood immunizations.¹⁹

In this study, we evaluate vaccine coverage for RV, DTaP, and PCV vaccines before and during the COVID-19 pandemic among a primarily insured cohort of infants within the first year of life. We explore potential inequities in RV vaccine administration and coverage by race and ethnicity, primary language, and Medicaid insurance.

METHODS

Study Design

We conducted a retrospective, observational study of pediatric patients within the VSD population to estimate RV, DTaP, and PCV vaccine coverage for infants born between January 1, 2018 and May 31, 2023, to evaluate associations between demographic and

health-seeking factors and delays in vaccine administration. The VSD is a collaborative project between the Centers for Disease Control and Prevention's (CDC's) Immunization Safety Office and 13 health care organizations contributing data for approximately 4% of the US population annually.^{20–22} Patients are included in the VSD cohort based on enrollment, defined by health insurance coverage, or for one VSD site empanelment, defined as having an ambulatory visit in the previous 12 months.²³ Thus, the population included in this study is primarily insured. This study was approved by the institutional review boards of all participating sites with a waiver of informed consent, and it followed the Strengthening the Reporting of Observational Studies in Epidemiology reporting guideline. This activity was reviewed by the CDC and is consistent with applicable federal law and CDC policy (see eg, 45 C.F.R. part 46.102[l][2], 21 C.F.R. part 56; 42 U.S.C. §241[d]; 5 U.S.C. §552a; 44 U.S.C. §3501 et seq).

Population

The study population was infants aged 0 to 12 months who were born from January 1, 2018, through May 31, 2023. We required that infants have a minimum of 9 months of enrollment in the first 12 months of life with at least 1 medical visit between 9 and 12 months at any of the 8 participating VSD sites to improve capture of vaccinations administered during the first year of life. Participating VSD sites are located in California, Washington, Oregon, Colorado, Minnesota, and Wisconsin.

Outcome Measures

Vaccines were identified from standardized VSD files, including administrations recorded in the electronic health record (EHR), medical or pharmacy claims, or bidirectional communication with jurisdictional immunization information systems.²¹ We evaluated vaccine coverage for monthly birth cohorts at age 5 months and 12 months. At age 5 months, we included first and second doses of RV and 2 doses of DTaP and PCV vaccines for infants born January 1, 2018, through May 31, 2023. At age 12 months, we evaluated completion of recommended doses of RV, DTaP, and PCV for infants born January 1, 2018, through October 31, 2022. There are 2 currently licensed RV vaccines: Rotarix (RV1) is a 2-dose series and Rotateq (RV5) is a 3-dose series. For PCV, we only included PCV13 in this evaluation. We evaluated coverage for individual vaccines and the combined UTD status for the recommended number of vaccine doses by age (Supplemental Table 1). To be considered valid, we required that vaccine administrations occurred by at least 42 days of life and that vaccines from the same vaccine series had at least 28 days between doses.

Stratification Variables

We included infant age, sex, race and ethnicity, both inpatient and outpatient health use, and Medicaid obtained from standardized VSD files that capture data from EHRs and claims databases. Infant race and ethnicity were grouped into the following categories: non-Hispanic white ("White"), non-Hispanic Black or African American ("Black"), non-Hispanic Asian ("Asian"), Hispanic or Latino, and "Other," which includes all other racial categories and missing race and ethnicity. Infant race and ethnicity were included to allow for assessment of racial and ethnic disparities and was based on data provided by the infant's caregiver. We defined inpatient health use as the number and duration of

inpatient encounters excluding birth hospitalizations: 0, at least 1 lasting 0 to 7 days, or at least 1 lasting more than 7 days. We defined outpatient health use as the number of outpatient primary care encounters (1–4 or ≥ 5 encounters) including both preventive care and acute care visits. Medicaid was defined as any Medicaid enrollment in the first year of life. We also included the infant's caregiver's primary language and need for interpreter. Primary language was categorized as English, Spanish, or non-English/non-Spanish. Need for interpreter was defined by whether a bilingual interpreter in English and caregiver's primary language was requested.

Statistical Methods

We calculated vaccination coverage at 5 and 12 months by dividing the number of infants who received the selected vaccinations by the number of eligible infants in each monthly birth cohort, defined as all infants born in a calendar month during the study period. We estimated 95% CI using a generalized linear model with binomial distribution and logit link function. Coverage at 5 months included the study period of June 2018 to October 2023 and coverage at 12 months was assessed from January 2019 through October 2023. We stratified results by infant race and ethnicity, primary language, need for interpreter, and Medicaid for RV vaccines only.

We identified 4 distinct time periods of vaccine administrations related to the COVID-19 pandemic based on known disruptions to care^{6,12} and posthoc trends in vaccination coverage: (1) prepandemic (ie, June 2018 through mid-March 2020), (2) age-limited preventive care (ie, mid-March through mid-May 2020), (3) expanded primary care (ie, mid-May 2020 through mid-June 2021), and (4) routine primary care (ie, mid-June 2021 through October 2023). We then assigned monthly birth cohorts to these time periods based on the expected timing of receiving first vaccine doses for 5-month coverage (ie, age 2 months) and second vaccine doses for 12-month coverage (ie, age 4 months). Monthly birth cohorts associated with the 4 time periods are shown in Supplemental Table 2.

We evaluated the association of the caregiver's primary language or need for interpreter, infant race and ethnicity, Medicaid, health care use, and time period with vaccine uptake. This was done using time-to-event analysis in multi-variable Cox proportional hazards regression models adjusted for the previously mentioned covariates and for uptake by 12 months, delay of first dose past 15 weeks. For models estimating RV uptake or UTD status a covariate indicating RV product (RV1 or RV5) was included. We report adjusted hazard ratios (aHR) with 95% CI. We estimated aHRs for time to first RV vaccine censoring at 5 months and time to second RV vaccine censoring at 12 months, comparing infant's racial and ethnic group and use of Medicaid or not by time period. We also evaluated the association between infant's race and ethnicity and time to first or second RV vaccine stratified by Medicaid. Analysis was performed using SAS/STAT and SAS/GRAPH software (Version 9.4, SAS Institute Inc.).

RESULTS

Population

We included 395 143 infants in 65 unique monthly birth cohorts: 48.4% female, 51.6% male, 14.7% non-Hispanic Asian (“Asian”), 5.8% non-Hispanic Black (“Black”), 34.2% Hispanic, and 31.8% non-Hispanic white (“White”) (Table 1). Spanish was reported as the primary language for 3.5% of caregivers, 2.0% reported a primary language other than English or Spanish, and 3.0% requested interpreter services at a medical visit. Medicaid was identified for 20.6%. Most (94.1%) infants had 5 or more primary care encounters in the first year of life, 6.1% of infants had 1 or more inpatient hospitalizations lasting 0 to 7 days, and 1.0% of infants had 1 or more inpatient hospitalization(s) lasting more than 7 days.

Vaccine Coverage

Vaccine coverage among infants by age 5 and 12 months is shown in Figure 1 and Supplemental Tables 3 and 4. Vaccine coverage at 5 months increased throughout the pre-pandemic period (Supplemental Table 3) and decreased during the pandemic. By the end of the evaluation period, October 2023, coverage for individual vaccines remained below pre-pandemic levels. UTD coverage at 5 months was 87.8% (95% CI 86.9–88.7) in February 2020 vs 80.8% (95% CI 79.8–81.8) in October 2023. Among infants aged 12 months across all time periods, coverage was highest for 3 doses of DTaP, followed by 3 doses of PCV, and then complete RV series. UTD coverage at 12 months was highest in January 2020 (92.3% [95% CI 91.6–92.9]) and decreased to 89.6% (95% CI 88.8–90.3) in October 2023 (Supplemental Table 4).

Factors Associated With Vaccine Uptake

Demographic factors associated with lower vaccine uptake for all 3 vaccines among infants at both age 5 and 12 months included Black race compared with white (aHR 0.86 [95% CI 0.85–0.87] and 0.84 [95% CI 0.83–0.85]), caregiver’s primary language that was not English or Spanish (aHR 0.95 [95% CI 0.92–0.97] and 0.97 [95% CI 0.94–0.99]) compared with English, and Medicaid (aHR 0.73 [95% CI 0.73–0.74] and 0.82 [95% CI 0.81–0.82]) compared with no Medicaid (Table 2). There was higher vaccine uptake for Asian infants at 5 and 12 months compared with white infants with UTD status 1.32 (95% CI 1.30–1.33) and 1.27 (95% CI 1.25–1.28), respectively. Health care use was also associated with vaccine uptake. There was lower vaccine uptake among infants having 1 to 4 primary care visits in the first year of life compared with those having at least 5 visits at both 5 months (aHR 0.50 [95% CI 0.49–0.51]) and 12 months (aHR 0.53 [95% CI 0.52–0.54]). Any inpatient admission in the first year of life compared with no inpatient admissions was also associated with lower vaccine uptake. Finally, there was lower uptake after the COVID-19 pandemic began compared with the pre-pandemic time period with lowest uptake occurring during age-limited preventive care.

RV Specific Analyses

Throughout the study period, coverage for 2 doses of RV vaccine by 5 months and complete RV series by 12 months was consistently lower for Black infants compared with infants

from other race and ethnic groups and for those with Medicaid compared with no Medicaid (Figure 2). There were no clear disparities in RV vaccine coverage noted for caregiver's primary language or need for interpreter (Supplemental Figure 1). Compared with white infants, Asian and Hispanic infants had higher uptake of the first RV vaccine by 5 months and second RV vaccine by 12 months across time periods (Table 3).

The identified disparities in uptake of RV vaccine by racial and ethnic groups are modified by having Medicaid. RV vaccine uptake among Black infants with no Medicaid compared with white infants with no Medicaid was 0.92 [95% CI 0.90–0.94] at 5 months and 0.86 [95% CI 0.85–0.88] at 12 months. In Black infants with Medicaid compared with white infants with Medicaid associations were 1.03 [95% CI 1.00–1.06] at 5 months and 0.94 [95% CI 0.91–0.97] at 12 months. Different levels of uptake by Medicaid were also found among Hispanic infants compared with white infants with and without Medicaid. At 5 months, RV vaccine uptake among Hispanic infants with Medicaid was 1.18 [95% CI 1.16–1.20] and without Medicaid 1.03 [95% CI 1.02–1.04]. At 12 months associations were 1.19 [95% CI 1.16–1.21] with Medicaid and 1.05 [95% CI 1.04–1.06] without Medicaid.

DISCUSSION

In this analysis of 395 143 infants in the VSD, we observed lower vaccine coverage for infants turning 5 months ($n = 395\ 143$) and 12 months ($n = 352\ 098$) during and following the COVID-19 pandemic compared with the prepandemic period. Throughout the study period, lower vaccination coverage was noted among infants whose race was Black and those with Medicaid. In addition, lower vaccine uptake was identified in infants with a non-English/non-Spanish primary language caregiver and those with fewer outpatient primary care visits in the first year of life. Higher vaccine uptake was identified among infants with Spanish primary language caregivers.

The COVID-19 pandemic affected pediatric immunization programs worldwide.^{7,24–26} Many routine assessments of vaccine coverage estimates focus on specific age groups, such as children aged 24 months from the National Immunization Survey.^{14–16} We focused on infants within the first year of life to evaluate the possible disproportionate consequences the COVID-19 pandemic may have had on RV vaccine coverage. Throughout the study period, coverage for 2 doses of RV vaccine at 5 months was similar to or higher than coverage for 2 doses of PCV, but at 12 months, PCV completion was higher than RV vaccine. This suggests differential catch-up of PCV compared with RV vaccine. RV vaccine age restrictions coupled with potential access issues such as changes in health insurance, transportation and language barriers, and difficulties scheduling convenient appointments may allow for catch-up of other routine childhood immunizations but not RV vaccine. Our finding of lower vaccine uptake among those with fewer primary care visits in the first year of life may be related barriers in accessing care or lower interest in preventive care and should be evaluated further.

Individuals with a primary language other than English face multiple barriers to accessing health care services, including vaccinations.²⁷ Our finding of lower vaccine uptake among patients with caregivers whose primary language is not English or Spanish as well as similar

or higher coverage among patients with caregivers whose primary language is Spanish is noteworthy. Because of sample size limitations, we did not stratify coverage by all primary language groups. However, these noted disparities highlight the importance of reporting on language when evaluating health disparities to further focus public health interventions aimed at improving language access for patients.²⁸

Inequities in vaccination coverage within the VSD population by race and ethnicity and Medicaid were present before the COVID-19 pandemic. We did not identify worsening of disparities by race and ethnicity due to the COVID-19 pandemic. However, we note that disparities by patient race and ethnicity vary when stratified by Medicaid. Further exploration of how interconnections between racial and ethnic disparities and other socioeconomic and cultural factors influence vaccination status is needed to understand the root causes of vaccine coverage inequities and to develop interventions that address them.

Limitations of this research should be noted; most importantly, the VSD represents primarily insured individuals. Overall, we observed high vaccine coverage in our population. Vaccination coverage may differ in populations that lack or have intermittent health insurance. Additionally, although a previous evaluation found the VSD population is representative of the US population on key demographic and socioeconomic variables, data from this study lacked representation from certain geographic areas including the southern and eastern areas of the United States.²⁰ Our inclusion criteria requiring a medical visit between age 9 and 12 months may bias our results toward those with more health care access. Although this would have less effect on our observed RV vaccine coverage due to the age limitations for administration, infants who were overdue for PCV and DTaP may have received catch-up vaccines during clinical visits between age 9 and 12 months. Coverage estimates may be lower in population groups with more difficulty in accessing health care. Next, because we combined patients whose caregivers were non-English and non-Spanish primary language speakers into one group, disparities may not have been identified in certain language subgroups. Further research should disaggregate language groups to provide language group-specific vaccine coverage estimates. We were unable to evaluate qualitative reasons for decreased vaccination coverage. Specifically, we are unable to determine the extent to which vaccine hesitancy may have affected vaccine coverage. Although a recent study did not find evidence for a change in the proportion of parents who were hesitant toward routine childhood immunizations after the onset of the COVID-19 pandemic compared with before the pandemic, it did find decreased trust in information parents receive about vaccines.²⁹ Coupling vaccine data obtained from objective sources with information about vaccine confidence and hesitancy will aid in understanding how personal beliefs, motivations, and behaviors influence vaccine coverage.

CONCLUSION

Three years after the start of the COVID-19 pandemic, coverage for selected routine childhood immunizations remained below prepandemic levels. Throughout the study period among a cohort of primarily insured infants, we identified lower vaccination coverage for infants who were Black, those who had caregivers whose primary language was neither English nor Spanish, and those with Medicaid. Although our findings highlight population

groups for whom focused interventions are needed to improve vaccine coverage, further understanding of how these factors may be related to other sociodemographic and cultural factors, availability of care, structural barriers to accessing care, and vaccine confidence, is needed. Future pandemics or other interruptions to public health and primary care infrastructure may result in further erosion of routine childhood immunization coverage with the potential for a resurgence of vaccine-preventable diseases.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Dr DeSilva conceptualized and designed the study, participated in interpretation of the data, drafted the initial manuscript, and critically reviewed and revised the manuscript. Mr Haapala assisted with study conceptualization and design, carried out the analyses, participated in interpretation of the data, and critically reviewed and revised the manuscript. Drs Vazquez-Benitez and Kharbanda assisted with conceptualization and design of the study, participated in interpretation of the data, and critically reviewed and revised the manuscript. Drs Daley, Lewin, Klein, Liles, Jackson, Williams, Donahue, and Yih provided input on the study's design, participated in interpretation of the data, and critically reviewed and revised the manuscript.

CONFLICT OF INTEREST DISCLOSURES:

Dr DeSilva's institution received payments from Westat, Inc. and the Minnesota Department of Health; Dr Vazquez-Benitez received research funding for unrelated work from Sanofi Pasteur and AbbVie; Dr Klein's institution received research support from Pfizer. Money was paid to her institution from Merck, and Sanofi Pasteur has received research support from Pfizer for COVID-19 vaccine clinical trials; Dr Williams has served as a content reviewer for Immunize 4 Good; Dr Donahue has received support from Janssen Vaccines and Prevention for an unrelated study. The other authors did not report any potential conflicts of interest.

ABBREVIATIONS

DTaP	diphtheria, tetanus, and acellular pertussis
EHR	electronic health record
UTD	up-to-date
PCV	pneumococcal conjugate vaccine
RV	rotavirus
RV1	Rotarix
RV5	Rotateq
VSD	Vaccine Safety Datalink

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WHAT'S KNOWN ON THIS SUBJECT:

The COVID-19 pandemic resulted in reductions in vaccine administrations for all pediatric age groups. Differences in pediatric vaccine coverage based on race, ethnicity, and insurance are well documented. Less is known about the pandemic's impact on these disparities.

WHAT THIS STUDY ADDS:

In this observational study from 8 US health systems, infant vaccine coverage decreased from February 2020 through October 2023. Factors associated with lower coverage included nonHispanic Black race, Medicaid insurance, non-English or non-Spanish primary language, and fewer outpatient visits.

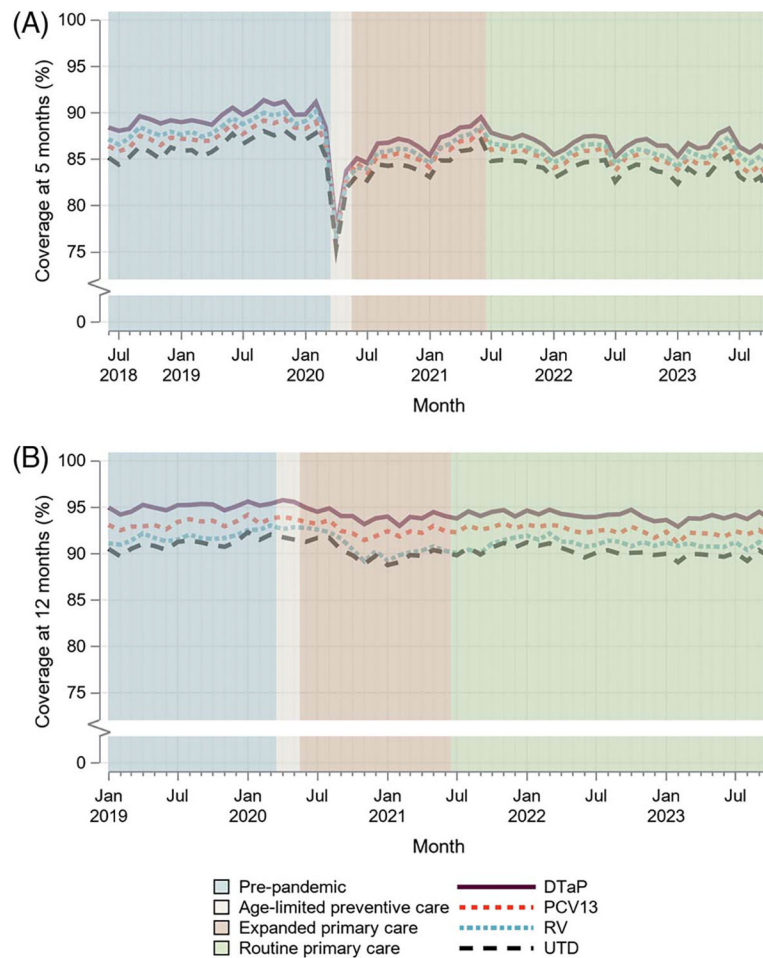
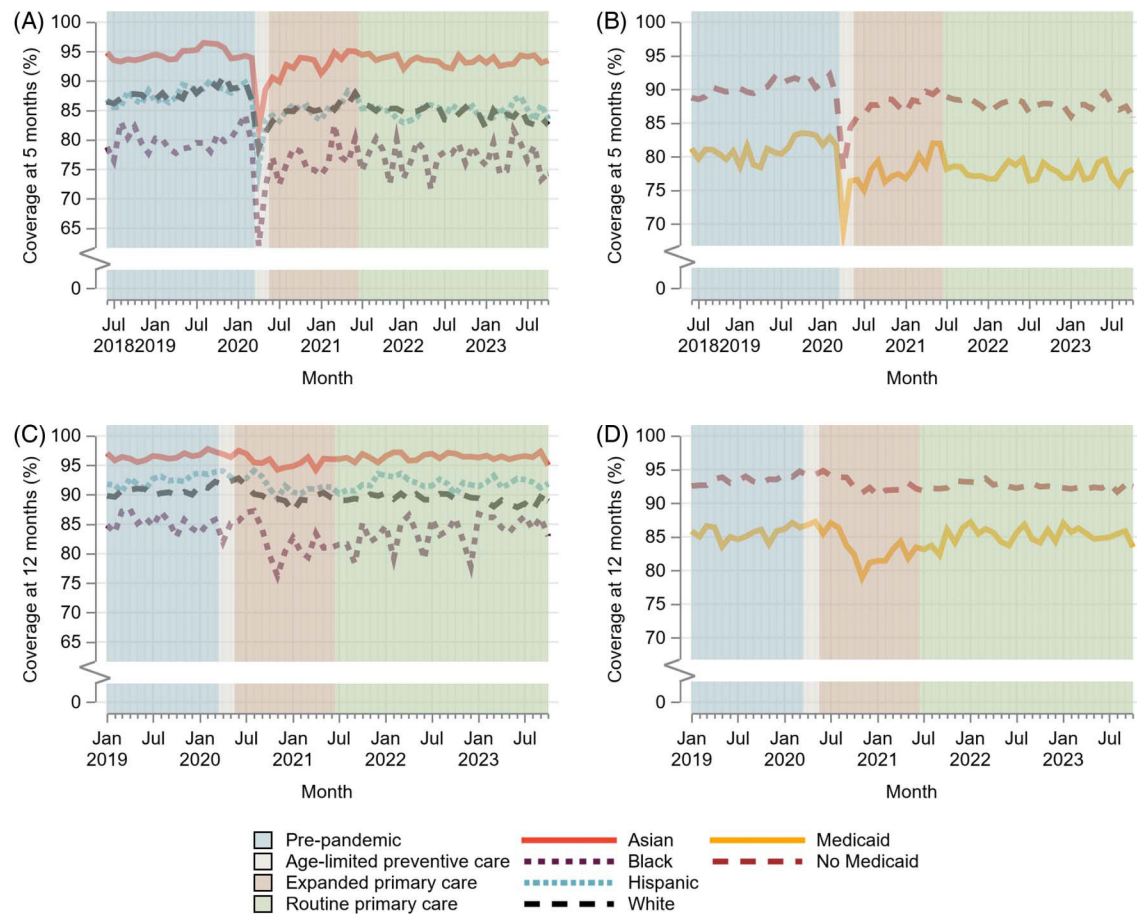


FIGURE 1.

Vaccine coverage^a for RV, DTaP and PCV at 5 months monthly birth cohorts born during January 1, 2018, through May 31, 2023 (A) and at 12 months for monthly birth cohorts born during January 1, 2018 through October 31, 2022 (B) from the VSD.

Abbreviations: DTaP, diphtheria, tetanus, and acellular pertussis; UTD, up-to-date; PCV, pneumococcal conjugate vaccine; RV, rotavirus; RV1, Rotarix; RV5, Rotateq; VSD, Vaccine Safety Datalink

^aCoverage at 5 months = 2 doses of RV, DTaP, and PCV evaluated individually and combined as UTD. Coverage at 12 months = 2 or 3 doses of RV depending on product (If a patient received RV5 for any doses, we counted 3 doses at 12 months as complete. If they received only RV1, we counted 2 doses at 12 months as complete) and 3 doses of DTaP and PCV evaluated individually and combined as UTD.

**FIGURE 2.**

RV vaccine dose 2 coverage at 5 months for monthly birth cohorts born during January 1, 2018 through May 31, 2023 and dose 2 or 3 coverage^a at 12 months for monthly birth cohorts born during January 1, 2018 through October 31, 2022 from the VSD stratified by race and ethnicity (A: 5 month coverage and C: 12 month coverage) and Medicaid (B: 5 month coverage and D: 12 month coverage).

Abbreviations: RV, rotavirus; RV1, Rotarix; RV5, Rotateq; VSD, Vaccine Safety Datalink

^aIf a patient received RV5 for any doses, we counted 3 doses at 12 months as complete. If they received only RV1, we counted 2 doses at 12 months as complete.

TABLE 1.Baseline Demographics of Included Pediatric Patients From 8 US Health Systems in the VSD, 2018–2023^a

Baseline Demographics	N (%)
Full cohort	395 143 (100.0)
Female	191 075 (48.4)
Male	203 948 (51.6)
Race and ethnicity	
Asian, non-Hispanic	58 256 (14.7)
Black, non-Hispanic	22 955 (5.8)
Hispanic	135 177 (34.2)
Other/unknown	53 250 (13.5)
White, non-Hispanic	125 505 (31.8)
Needs interpreter	12 013 (3.0)
Primary language	
English/Unknown	373 535 (94.5)
Spanish	13 778 (3.5)
Non-English/non-Spanish	7830 (2.0)
Medicaid insurance	81 321 (20.6)
Outpatient primary care encounters	
1–4 visits	23 124 (5.9)
5+ visits	372 019 (94.1)
Inpatient encounters	
0	366 859 (92.8)
1+, lasting 0–7 d	24 213 (6.1)
1+, lasting >7 d	4071 (1.0)

Abbreviation: VSD, Vaccine Safety Datalink

^a Includes data from children born January 1, 2018, through May 31, 2023.

TABLE 2.

Factors associated with RV, DTaP, and PCV vaccine uptake by 5 months for children born January 1, 2018 through May 31, 2023 and 12 months for children born January 1, 2018 through October 31, 2022 in the VSD reported as aHR^a with 95% CIs

Patient Characteristics	aHR ^a (95% CI)							
	Vaccine Uptake by 5 mos				Vaccine Uptake by 12 mos			
	DTaP (dose 2)	PCV (dose 2)	RV (dose 2)	UTD ^b	DTaP (dose 3)	PCV (dose 3)	RV (dose 2/3)	UTD ^b
Language (ref: English)								
Non-English/non-Spanish	0.93 (0.91–0.96)	0.94 (0.92–0.97)	0.94 (0.92–0.97)	0.95 (0.92–0.97)	0.95 (0.93–0.98)	0.97 (0.94–0.99)	0.95 (0.93–0.98)	0.97 (0.94–0.99)
Spanish	1.04 (1.02–1.07)	1.05 (1.02–1.08)	1.05 (1.02–1.07)	1.05 (1.03–1.08)	1.07 (1.05–1.10)	1.07 (1.04–1.10)	1.04 (1.02–1.07)	1.07 (1.04–1.09)
Need interpreter (ref: no/unknown)	0.97 (0.94–1.00)	0.97 (0.94–1.00)	0.97 (0.94–1.00)	0.97 (0.94–1.00)	1.00 (0.97–1.03)	1.00 (0.97–1.02)	1.00 (0.97–1.03)	0.99 (0.96–1.02)
Inpatient use (ref: none)								
1+, lasting 0–7 d	0.96 (0.95–0.98)	0.97 (0.95–0.98)	0.95 (0.93–0.96)	0.96 (0.94–0.97)	0.96 (0.94–0.97)	0.96 (0.94–0.97)	0.95 (0.93–0.96)	0.94 (0.92–0.95)
1+, lasting > 7 d	0.80 (0.77–0.83)	0.81 (0.79–0.84)	0.63 (0.61–0.65)	0.70 (0.67–0.72)	0.83 (0.80–0.85)	0.84 (0.81–0.87)	0.61 (0.59–0.64)	0.67 (0.64–0.69)
Primary care use 1–4 visits (ref: 5+ visits)	0.51 (0.50–0.52)	0.50 (0.49–0.51)	0.51 (0.50–0.52)	0.50 (0.49–0.51)	0.53 (0.52–0.54)	0.52 (0.51–0.53)	0.44 (0.43–0.45)	0.53 (0.52–0.54)
Race and ethnicity (ref: Non-Hispanic white)								
Non-Hispanic Asian	1.26 (1.25–1.28)	1.31 (1.29–1.32)	1.28 (1.27–1.30)	1.32 (1.30–1.33)	1.28 (1.27–1.30)	1.28 (1.26–1.29)	1.35 (1.33–1.36)	1.27 (1.25–1.28)
Non-Hispanic Black	0.84 (0.82–0.85)	0.86 (0.85–0.88)	0.85 (0.83–0.86)	0.86 (0.85–0.87)	0.83 (0.82–0.84)	0.84 (0.83–0.85)	0.90 (0.88–0.91)	0.84 (0.83–0.85)
Hispanic	0.99 (0.98–1.00)	1.02 (1.01–1.03)	1.01 (1.00–1.02)	1.03 (1.02–1.04)	1.01 (1.00–1.02)	1.02 (1.01–1.03)	1.06 (1.05–1.07)	1.02 (1.01–1.03)
Other/unknown	1.02 (1.01–1.03)	1.03 (1.02–1.04)	1.03 (1.01–1.04)	1.03 (1.02–1.05)	1.02 (1.01–1.03)	1.02 (1.01–1.03)	1.05 (1.04–1.06)	1.02 (1.01–1.03)
Medicaid (ref: no Medicaid)	0.73 (0.72–0.74)	0.74 (0.73–0.75)	0.73 (0.73–0.74)	0.73 (0.73–0.74)	0.82 (0.81–0.82)	0.82 (0.81–0.83)	0.76 (0.75–0.76)	0.82 (0.81–0.82)
Time period (ref: pre-pandemic ^c)								
Age-limited preventive care ^d	0.75 (0.74–0.77)	0.78 (0.77–0.80)	0.76 (0.75–0.78)	0.79 (0.77–0.80)	0.82 (0.80–0.83)	0.84 (0.82–0.85)	0.81 (0.80–0.83)	0.84 (0.82–0.86)
Expanded primary care ^e	0.93 (0.92–0.94)	0.95 (0.94–0.96)	0.94 (0.93–0.94)	0.95 (0.94–0.96)	0.97 (0.96–0.97)	0.98 (0.97–0.99)	0.94 (0.93–0.95)	0.98 (0.97–0.99)
Routine primary care ^f	0.89 (0.89–0.90)	0.91 (0.90–0.91)	0.90 (0.89–0.91)	0.91 (0.90–0.91)	0.92 (0.91–0.93)	0.93 (0.92–0.94)	0.93 (0.93–0.94)	0.93 (0.92–0.94)

Abbreviations: aHR, adjusted hazard ratios; DTaP, diphtheria, tetanus, acellular pertussis; ref, reference group; UTD, up-to-date; PCV, pneumococcal conjugate vaccine; RV, rotavirus; VSD, Vaccine Safety Datalink

^a Adjusted for sex, primary language, race and ethnicity, health use, need for interpreter, insurance type, site, and study period. RV uptake and UTD status were also adjusted for RV product (RV1 or RV5) and for uptake by 12 months, delay of first dose past 15 weeks.

^b Received all 3 vaccines in the time frame outlined in Supplemental Table 1.

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^c June 2018 through mid-March 2020.
^d Mid-March through mid-May 2020.
^e Mid-May 2020 through mid-June 2021.
^f Mid-June 2021 through October 2023.

TABLE 3.

Differences in time to first rotavirus vaccination by 5 months for children born January 1, 2018 through May 31, 2023 or second rotavirus vaccine by 12 months for children born January 1, 2018 through October 31, 2022 in the VSD by race/ethnicity, Medicaid, and COVID-19 pandemic time periods using HR with 95% CIs

Patient Characteristics	HR ^a (95% CI)				
	Time Periods				Medicaid
	Prepandemic	Age-Limited Preventive Care	Expanded Primary Care	Routine Primary Care	
Rotavirus Dose 1 by 5 mos	Born Jan 2018–Dec 2019	Born Jan 2020–Feb 2020	Born Mar 2020–Apr 2021	Born May 2021–May 2023	No Medicaid
Race and ethnicity (ref: non-Hispanic white)					
Non-Hispanic Asian	1.25 (1.23–1.27)	1.14 (1.08–1.22)	1.22 (1.20–1.25)	1.27 (1.25–1.29)	1.31 (1.27–1.35)
Non-Hispanic Black	0.95 (0.93–0.97)	0.91 (0.83–1.00)	0.91 (0.89–0.95)	0.95 (0.93–0.97)	1.03 (1.00–1.06)
Hispanic	1.05 (1.03–1.06)	1.08 (1.03–1.14)	1.06 (1.04–1.08)	1.06 (1.05–1.08)	1.18 (1.16–1.20)
Other/unknown	1.05 (1.03–1.07)	1.02 (0.95–1.08)	1.01 (0.99–1.04)	1.05 (1.03–1.06)	1.07 (1.04–1.10)
Medicaid (ref: no Medicaid)	0.74 (0.73–0.75)	0.76 (0.72–0.80)	0.76 (0.75–0.77)	0.78 (0.77–0.79)	
Rotavirus dose 2 by 12 mos	Born Jan 2018–Oct 2019	Born Nov 2019–Dec 2019	Born Jan 2020–Feb 2021	Born Mar 2021–Oct 2022	
Race and ethnicity (ref: non-Hispanic white)					
Non-Hispanic Asian	1.28 (1.26–1.30)	1.13 (1.07–1.20)	1.28 (1.26–1.31)	1.34 (1.31–1.36)	1.37 (1.33–1.42)
Non-Hispanic Black	0.87 (0.85–0.89)	0.79 (0.72–0.87)	0.84 (0.81–0.87)	0.90 (0.88–0.93)	0.94 (0.91–0.97)
Hispanic	1.03 (1.02–1.05)	1.00 (0.95–1.05)	1.04 (1.02–1.06)	1.05 (1.03–1.06)	1.19 (1.16–1.21)
Other/unknown	1.05 (1.03–1.07)	0.99 (0.92–1.05)	1.01 (0.99–1.04)	1.06 (1.04–1.08)	1.04 (1.01–1.07)
Medicaid (ref: Other/unknown insurance)	0.76 (0.75–0.77)	0.80 (0.76–0.84)	0.76 (0.75–0.77)	0.78 (0.77–0.79)	
					1.29 (1.27–1.30)
					0.86 (0.85–0.88)
					1.01 (1.00–1.02)
					1.05 (1.04–1.06)

Abbreviations: aHR, adjusted hazard ratio; HR, hazard ratio; ref, reference group; VSD, Vaccine Safety Datalink

^a Adjusted for sex, primary language, race and ethnicity, health use, need for interpreter, insurance type, site, study period, and delay of first dose past 15 weeks.