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Temporal Trends in Undervaccination: A Population-Based Cohort Study

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Abstract

Introduction: Monitoring the trends in undervaccination, including that because of parental vaccine refusal or delay, can inform public health responses directed at improving vaccine confidence and vaccination coverage.

Methods: A retrospective cohort study was conducted in the Vaccine Safety Datalink. The cohort included all children born in 2004–2017 with ≥3 well-child visits between ages 2 and 23 months. Using electronic health record–based vaccination data, the average days undervaccinated was calculated for each child. Undervaccination patterns were assessed through age 23 months. Temporal trends were inspected for inflection points and were analyzed using linear regression.

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SUPPLEMENTAL MATERIAL

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Nested within the cohort study, a survey was conducted to compare parent reports of vaccine refusal or delay with observed vaccination patterns. Data were analyzed in 2020.

Results: The study cohort consisted of 808,170 children. The percentage of children with average days undervaccinated=0 (fully vaccinated, no delays) rose from a nadir of 47.1% for the birth year 2008 to 68.4% for the birth year 2017 (p_{trend}<0.001). The percentage with no vaccines rose from 0.35% for the birth year 2004 to 1.28% for the birth year 2017 (p_{trend}<0.001). Consistent vaccine limiting was observed in 2.04% for the birth year 2017. Omission of measles, mumps, and rubella vaccine peaked at 4.76% in the birth year 2007 and declined thereafter (p_{trend}<0.001). On the parent survey (response rate 60.2%), a high proportion of parents of the most undervaccinated children reported refusing or delaying vaccines.

Conclusions: In a 14-year cohort study, vaccination timeliness has improved. However, the small but increasing number of children who received no vaccines by age 23 months warrants additional attention.

INTRODUCTION

Although vaccination coverage among U.S. children is high relative to historical rates,[1,2] sustaining high coverage remains challenging because of vaccination barriers (e.g., related to access, affordability, and missed opportunities[1,3–5]) and parental vaccine hesitancy.[6,7] More than 10% of parents report having refused or delayed vaccines for their children,[8–10] and approximately 1.2% of children born in 2016 and 2017 received no vaccines by age 24 months.[2] In 2015, the National Vaccine Advisory Committee, responding to the challenges posed by vaccine hesitancy, recommended enhancing the nation's system for monitoring vaccine confidence and vaccination coverage.[11] Specifically, the National Vaccine Advisory Committee proposed utilizing data from multiple sources, including electronic health records (EHRs), immunization information systems (IISs), and parent surveys, to track temporal trends in confidence and coverage.[11,12]

Several approaches with contrasting strengths and limitations have been used to assess undervaccination from parental vaccine hesitancy. The National Immunization Survey-Child (NIS-Child) is a random-digit-dial survey of parents with subsequent provider verification of vaccination histories.[1] NIS-Child produces nationally representative immunization coverage estimates[1,5,13] and has been used to quantify the proportion of children completely unvaccinated[1] and the proportion after an alternate or unclassifiable vaccination schedule.[14] Although data are weighted to account for nonresponse or unverified vaccination histories, residual bias could nonetheless influence results,[15] and NIS-Child response rates have declined over time.[1,5,13,16,17] State and regional IIS data have also been used to examine undervaccination patterns suggestive of parental vaccine hesitancy.[18–20] IIS vaccination data have limitations as well, because of provider nonparticipation, incomplete reporting of vaccination data, and migration of children out of state.[21]

As recommended by the National Vaccine Advisory Committee,[11] the integration of EHR-based vaccination data with other data sources may complement the existing approaches to monitoring coverage. The primary objective of this study is to assess temporal trends in undervaccination using EHR data from a large research network (the Vaccine Safety

Datalink [VSD][22–24]), with a focus on undervaccination patterns that may indicate parental vaccine hesitancy. A secondary study objective is to assess the completeness of VSD EHR–based vaccination data[25,26]; this will be accomplished by conducting a survey of parents nested within the larger cohort study and comparing parent reports of refusal and delay with observed vaccination patterns.

METHODS

This study was conducted in the VSD network, a collaboration between the Centers for Disease Control and Prevention and 8 large medical care organizations (referred to as *sites*).[22–24] All VSD sites (Denver Health, HealthPartners, Marshfield Clinic, Kaiser Permanente [KP] Washington, KP Northwest, KP Northern California, KP Southern California, and KP Colorado) participated in the cohort study; all sites except Denver Health, which had recently joined the VSD,[27] participated in the parent survey. The VSD population of >11 million individuals is similar to the U.S. population with respect to demographic and socioeconomic characteristics.[24] VSD sites serve privately and publicly insured patients[22–24]; Denver Health also serves uninsured patients.[28] The IRB at KP Colorado approved the study, and participating sites ceded research oversight to KP Colorado. Written consent for survey participation was not required, and parents could opt out of the survey. The observation period for assessing vaccination trends was January 1, 2004 through December 31, 2019; the parent survey was conducted from January 30, 2019 through June 15, 2019.

Study Population

The study cohort comprised all children born in 2004–2017 who were seen for care at a VSD site. For 7 VSD sites with health insurance enrollment information,[22,23] continuous health insurance enrollment was required from age ≤42 days through age 23 months. For Denver Health, ≥1 visit to primary care between age 6 and 23 months was required.[27] Children were excluded from the study cohort if a medical contraindication to vaccination was present (as identified by encounter diagnosis codes) or if vaccine data errors were identified (e.g., unspecified vaccine type, vaccine date before the date of birth). Children were also excluded if they were not receiving routine care at a VSD site, defined as having <2 well-child visits between birth and age 11 months or as no well-child visits between ages 12 and 23 months.

Measures

The VSD vaccine data are primarily derived from the site EHR and claims data[22,23] and appear to be highly accurate.[25,26,29] At 6 VSD sites, vaccine data were supplemented by data from state IISs; relatively few additional vaccines (3% or less) were identified from IIS data. After compiling vaccination data for the study cohort, a previously published algorithm[30–32] was used to calculate the average days undervaccinated (ADU) for each child. In the context of studying parental vaccine hesitancy, ADU is a useful metric because it measures vaccination timeliness as well as receipt.[30–32] For each vaccine recommended in the first 23 months of life (except for hepatitis A and influenza vaccines), ADU measures when a vaccine dose was administered relative to when the dose was recommended in

Advisory Committee on Immunization Practices immunization schedules.[33–35] Hepatitis A and influenza vaccines did not contribute to ADU calculations; hepatitis A did not contribute because of the long window for on-time vaccination (age 12–23 months), and influenza did not contribute because of the seasonal nature of vaccine administration.[33–35] The ADU algorithm incorporated multiple vaccine schedule specifications,[33–35] including minimum ages, minimum intervals between doses, different dose requirements for different products of the same vaccine type, changes in recommendations over time, and shortage-related recommendations. ADU at age 23 months could range from a minimum of 0 days (i.e., fully vaccinated, no delays) to a maximum of 637 days (i.e., completely unvaccinated).[30–32]

For children with ADU >0, specific patterns of undervaccination were identified. The patterns were defined a priori on the basis of the previous work[1,18,19,32] and were designed to capture the approaches recommended by advocates of alternative (i.e., contrary to the recommended) vaccination schedules.[36,37] The examined patterns included receiving no vaccines by ages 4, 6, 12, and 23 months; receiving diphtheria–tetanus toxoid and acellular pertussis (DTaP) vaccine and rotavirus vaccines on a different day from that of pneumococcal conjugate vaccine (PCV) and *Haemophilus influenzae* type-b conjugate vaccine (Hib); or consistent vaccine limiting (≤2 vaccines administered at every vaccination visit before age 12 months).[1,18,19,32] In addition, temporal trends in the omission of vaccine series (e.g., not receiving any doses of a given series) were examined.

Among children with identified patterns of undervaccination, EHR data were searched for encounter diagnosis codes for parental vaccine refusal (ICD-9-CM codes V64.05 and V64.06 and ICD-10-CM codes Z28.1, Z28.20, Z28.21, Z28.82). Previous work has shown that when these diagnosis codes are present, they are a highly specific indicator of intentional parental vaccine refusal.[32]

Survey Sample Frame, Design, and Administration

The survey objective was to compare parent reports of vaccine refusal and delay with the patterns observed in EHR-derived vaccination data. To develop a survey sample frame, children were grouped into 6 mutually exclusive categories on the basis of ADU. A total of 5 categories represented quintiles of ADU: for example, ADU Quintile 1 represented children with a relatively small (ADU range=1.0–9.1 days) number of days undervaccinated, whereas children in ADU Quintile 5 were highly undervaccinated or had received no vaccines (ADU range=205.5–457.0 days). The sixth group comprised children with ADU=0 (i.e., fully vaccinated, no delays). To align with NIS-Child methods,[5,13,16] surveys were conducted among parents of children aged 19–35 months as of January 28, 2019. To develop the survey sample frame, ADU was assessed at age 18 months (whereas ADU was assessed at age 23 months for the cohort study). Children were randomly sampled within the 6 ADU groups, with sampling stratified by VSD site. The survey was powered to provide a 2-sided CI width of 14% around a point estimate of parent-reported vaccine refusal or delay, conservatively assuming 50% survey response and 50% of parents in any ADU category confirming intentional refusal/delay. On the basis of these power calculations, the survey sample size was 2,400 to yield 1,200 completed surveys.

On the basis of a previously developed instrument,[25,26] the survey assessed whether any vaccines had been received someplace other than at their VSD site and whether parents had refused or delayed vaccines for their child for reasons other than illness or allergy.[38,39] The survey included a validated measure of parental vaccine hesitancy: the Parent Attitudes about Childhood Vaccines short scale.[38,39] This 5-item scale included questions about vaccine safety, efficacy, and overall concern, with 3 answer choices (*yes, don't know, no*). Each answer was scored 0, 1, or 2 points, scores were summed across items, and the total score ranging from 0 to 10 was used to assign the degree of vaccine hesitancy.[38,39]

Surveys were administered by postal mail (up to 3 attempts) and e-mail (up to 3 attempts). Parents also received an automated telephone reminder. Per local research regulations, 1 VSD site was not allowed to contact parents by e-mail or telephone; at this site, a fourth survey was mailed. A $30 gift card was provided to all respondents as remuneration.

Statistical Analysis

After constructing the study cohort, ADU was assessed at age 23 months, and children with ADU >0 were grouped into hierarchical, mutually exclusive patterns of undervaccination. For each pattern, temporal trends by birth year were plotted, inspected for possible inflection points, and analyzed using continuous linear regression to test for statistical significance. For analyses of parent surveys, respondents were compared with nonrespondents using chi-square and Student's *t*-tests. Analyses of survey responses accounted for the complex sampling strategy, with weighting applied to account for the probability of being sampled and for the survey response probability. Analyses also incorporated a design effect to account for stratification by the VSD site. Weighted percentages for survey responses were reported with Clopper–Pearson 95% CIs. Analyses were conducted using SAS, version 9.4; data were analyzed in 2020. Most results were presented to 1 decimal place; the prevalence of undervaccination patterns, some of which were rare, were reported to 2 decimal places.

RESULTS

A total of 864,041 children were born from January 1, 2004 through December 31, 2017 with continuous health insurance enrollment. As Appendix Figure 1 (available online) shows, 55,871 (6.5%) did not meet study inclusion criteria, resulting in a study cohort of 808,170 children. The demographic and clinical characteristics of the study cohort are presented in Table 1. The size of the study cohort ranged from 48,051 to 64,817 per birth year. Regarding race/ethnicity, 27.1% of the study cohort was Hispanic, 14.5% was non-Hispanic Asian, and 5.8% was non-Hispanic Black; race/ethnicity data were missing for 7.2% of the study cohort. Trends in ADU=0 (fully vaccinated, no delays) by birth year are shown in Appendix Figure 2 (available online); the percentage of children with ADU=0 increased since birth year 2008, with a prevalence of 68.4% in the birth year 2017 (birth year 2008–2017, $p_{trend}<0.001$).

Temporal trends in specific patterns of undervaccination assessed at age 23 months are shown in Figure 1. The 2 most common patterns were no vaccines (Panel A) and consistent vaccine limiting (Panel F). The numeric values for these specific patterns are shown in Appendix Table 1 (available online). The percentage with no vaccines rose from 0.35%

for children born in 2004 to 1.28% for those born in 2017 (p_{trend}<0.001), an average increase of 0.07% per year. Delayed start to vaccination was relatively rare: for children born in 2017, the percentage with their first vaccine at ages 4–5, 6–11, and 12–23 months was 0.33%, 0.20%, and 0.24%, respectively. Children whose parents followed a specific alternative schedule (DTaP and rotavirus vaccines on a different day from that of PCV and Hib)[36] peaked at 0.24% among children born in 2008 and significantly declined thereafter (birth year 2008–2017, p_{trend}<0.001). Consistent vaccine limiting was observed in 2.04% of the children born in 2017. Additional characteristics of these undervaccination patterns are shown in Appendix Table 2 (available online). Children in these patterns remained highly undervaccinated through age 23 months, with mean ADU >250 days for all patterns. Children with a specific alternative schedule and those who had consistently vaccine limiting averaged >9 vaccination visits by age 23 months.

Temporal trends in the omission of the entire vaccine series are presented in Table 2. The least frequently omitted series was DTaP. The most frequently omitted series were rotavirus and influenza vaccines. The omission of measles, mumps, and rubella vaccine peaked at 4.76% in children born in 2007 and significantly (p_{trend}<0.001) declined thereafter to 3.52% among children born in 2017. The omission of varicella vaccine also peaked in children born in 2007 at 5.24% and declined (p_{trend}<0.001) thereafter to 4.15% among children born in 2017.

Healthcare providers' use of encounter diagnosis codes to document parental vaccine refusal, uncommon during the early years of the study observation period, became more widespread by the end of the observation period. For children born in 2017 who received no vaccines by age 23 months, 88.6% had a diagnosis of parental vaccine refusal. For children born in 2017 receiving their first vaccine at ages 4–5, 6–11, and 12–23 months, a refusal code was documented for 66.2%, 77.9%, and 84.4%, respectively. For children born in 2017 who received DTaP and rotavirus vaccine on a different day from that of PCV and Hib, a refusal code was present for 65.9%; for those whose parents were consistently vaccine limited, a code was present for 67.3%.

The survey response rate was 60.2% (1,444 of 2,398 parents responded). Survey respondents differed from nonrespondents in several respects (Appendix Table 3, available online). Survey response was lower among the more highly undervaccinated (e.g., for higher ADU quintiles, p<0.001). Survey respondents were more likely to be non-Hispanic White or Asian and less likely to be non-Hispanic Black or Hispanic (p<0.001). The likelihood of having a vaccine refusal diagnosis code also differed (21.9% among respondents vs 29.0% among nonrespondents, p<0.001).

As shown in Table 3, there was a strong association between parents' degree of vaccine hesitancy and their child's observed vaccination status as represented by the ADU category. For example, 5.8% (95% CI=3.7, 7.8) of the fully vaccinated (ADU=0) compared with 56.5% (95% CI=45.4, 67.5) of the highly undervaccinated (ADU Quintile 5) were classified as having high parental hesitance on the 5-item Parent Attitudes about Childhood Vaccines short scale.[38,39] Similarly, parents' vaccine−related attitudes, particularly regarding vaccine limiting and vaccine safety, differed across ADU categories (Appendix Table 4, available

online), and a high proportion of parents of the most undervaccinated children reported refusing or delaying vaccines.

DISCUSSION

Using EHR vaccination data supplemented by IIS data, trends in specific undervaccination patterns were assessed in a population-based cohort of >800,000 children for over 14 birth years. The study focused on patterns likely to indicate intentional parental vaccine refusal or delay, and a parent survey nested within the cohort study confirmed a high degree of hesitancy among parents of the most undervaccinated children. The observed trends in undervaccination patterns were complex: although vaccination timeliness improved in recent years and omission of vaccines such as measles, mumps, and rubella vaccine and varicella vaccine declined, a small but slowly increasing number of children received no vaccines by age 23 months. Although very few parents followed a specific alternative vaccination schedule,[36] consistent vaccine limiting was more prevalent, which suggests that the concern about vaccines being given too many, too soon persists.[40,41]

The use of EHR-based vaccination data from large research networks such as the VSD[22–24,42] may mitigate some of the limitations of existing systems for monitoring vaccination coverage. Although NIS-Child[1,5,13] remains the gold standard for surveillance of national vaccination trends, achieving high survey response rates is challenging; and as suggested by the survey presented in this paper, NIS-Child findings could be biased if vaccine-hesitant parents were less likely to respond than vaccine-accepting parents. In comparison, the approach taken in this investigation involved defining a population-based cohort and incorporating additional data elements (e.g., insurance enrollment information, the use of well-child visits, and encounter diagnoses of parental vaccine refusal) into the study design to enhance internal validity. Although IISs can also monitor vaccination coverage,[21] the lack of any accompanying EHR-based encounter data makes it difficult to determine whether children with few documented vaccines are truly undervaccinated.[19] Movement of children out of state also complicates the assessments of undervaccination in IIS.

Interventions to improve vaccination coverage and timeliness may differ between vaccine-hesitant parents and parents facing vaccination barriers.[3,4] For parents who refuse or delay some or all vaccines, intensive interactions may be needed, beginning during pregnancy and involving multiple touch points throughout early childhood.[43–46] For parents encountering barriers, evidence-based strategies to improve coverage include parent reminders, provider prompts, standing orders, and interventions targeted at reducing missed opportunities.[47] It is important to note that in total, the 6 specific patterns tracked in this study represented <5% of the study cohort, which was small relative to the proportion undervaccinated but without a discernable pattern. Among mildly undervaccinated children, vaccine hesitancy was uncommon on the parent survey, suggesting that vaccination barriers were operant for at least some of these families.

Limitations

The study findings are subject to several potential limitations. First, misclassification of vaccination status may have occurred,[25,26] such as if vaccines were given outside a VSD site and not available through IIS interfaces. Second, when undervaccination was observed, it was not possible to conclusively determine the reasons for undervaccination; although the specific patterns documented appeared to represent intentional parental vaccine refusal or delay, other reasons for nonvaccination may have been present. Third, VSD sites, including Denver Health, utilize multiple strategies to maintain high vaccination coverage[42] (e.g., patient reminders and provider prompts); undervaccination may be greater in settings without these resources. Fourth, the VSD population has stable health insurance[22–24] (except Denver Health patients, some of whom are uninsured[28]), which may limit study generalizability to other populations. Finally, response bias could have affected survey findings, particularly because parents who had refused or delayed vaccines were less likely to respond to the survey than parents who had not.

CONCLUSIONS

This study used EHR-based vaccination data from a large research network to examine the trends in undervaccination for over 14 birth years, an approach well aligned with recent recommendations to incorporate EHR-based data into existing public health surveillance systems.[48,49] Although the percentage of children receiving no vaccines increased over the study observation period, the absolute percentage (1.28% for children born in 2017) remained small, and vaccination timeliness improved for recent birth cohorts. Continued surveillance using multiple data sources will be critical to developing public health interventions to maintain high national vaccination coverage.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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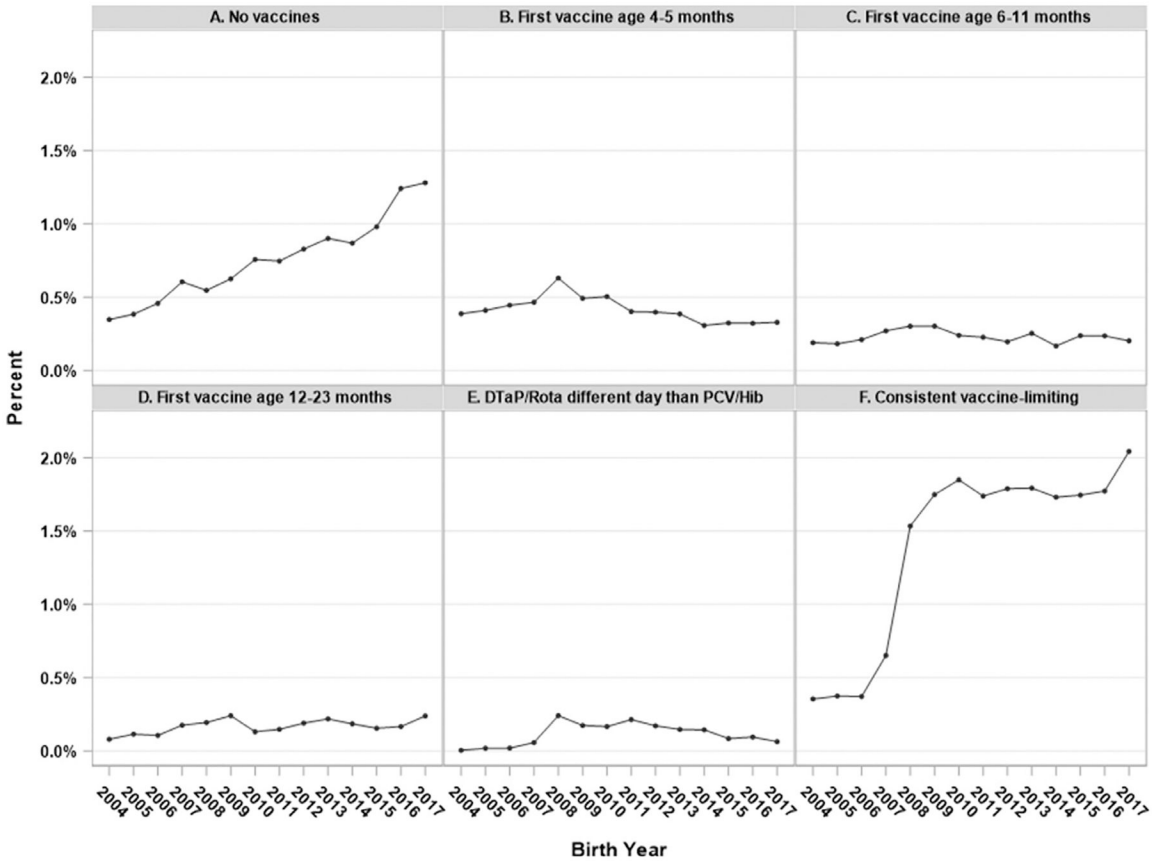

Figure 1.

Temporal trends in specific patterns of undervaccination assessed at age 23 months, by birth year, Vaccine Safety Datalink.

DTaP, diphtheria–tetanus toxoids and acellular pertussis vaccine; Hib, *Haemophilus influenzae* type-b conjugate vaccine; PCV, pneumococcal conjugate vaccine; Rota, Rotavirus vaccine.

Table 1.

Demographic and Clinical Characteristics of the Cohort Born in 2004 Through 2017 and Followed Through 2019

Characteristics	Value
Total cohort, *n*	808,170
Sex, *n* (%)	
Female	393,886 (48.7)
Male	414,284 (51.3)
Race/ethnicity, *n* (%)	
Non-Hispanic White	327,277 (40.5)
Non-Hispanic Black	46,540 (5.8)
Non-Hispanic Asian	117,254 (14.5)
Hispanic	218,962 (27.1)
Other race/ethnicity	40,343 (5.0)
Missing race/ethnicity	57,794 (7.2)
Birth year, *n* (%)	
2004	48,051 (5.9)
2005	49,515 (6.1)
2006	52,385 (6.5)
2007	54,404 (6.7)
2008	59,644 (7.4)
2009	60,167 (7.4)
2010	59,319 (7.3)
2011	58,709 (7.3)
2012	59,299 (7.3)
2013	58,391 (7.2)
2014	58,701 (7.3)
2015	61,085 (7.6)
2016	63,683 (7.9)
2017	64,817 (8.0)
Chronic conditions based on PMCA, *n* (%)	
No complex or chronic conditions	675,848 (83.6)
Noncomplex chronic condition	97,882 (12.1)
Complex chronic condition	34,440 (4.3)
Outpatient utilization birth through age 11 months	
Well-child encounters, mean (SD)	4.3 (0.8)
Well-child encounters, median	4.0
Outpatient nonwell, non-ED encounters, mean (SD)	5.7 (5.0)
Outpatient nonwell, non-ED encounters, median	5.0
Outpatient utilization from age 12 through 23 months	
Well-child encounters, mean (SD)	2.2 (0.8)
Well-child encounters, median	2.0

Characteristics	Value
Outpatient nonwell, non-ED encounters, mean (SD)	4.0 (4.9)
Outpatient nonwell, non-ED encounters, median	3.0

ED, emergency department; PMCA, Pediatric Medical Complexity Algorithm.

Table 2.

Temporal Trends in the % of Children Who Received No Doses of a Recommended Vaccination Series

Year of birth	No DTaP vaccine,%	No Hib,%	No PCV,%	No hepatitis B vaccines,%	No polio vaccines,%	No rotavirus vaccines,%	No MMR vaccine,%	No varicella vaccine,%	No hepatitis A vaccines,%	No influenza vaccines,%
2004	0.50	0.55	0.78	0.96	0.67	NR[a]	2.10	3.81	NR[a]	31.89
2005	0.50	0.58	0.75	1.02	0.70	NR[a]	2.29	3.42	NR[a]	31.25
2006	0.63	0.72	0.85	1.10	0.88	NR[a]	3.33	4.15	NR[a]	28.09
2007	0.86	0.97	1.10	1.50	1.28	15.19	4.76	5.24	10.37	27.29
2008	0.80	0.97	1.10	2.08	1.36	9.75	4.53	4.82	8.98	22.39
2009	0.82	1.08	1.17	2.37	1.49	7.50	3.97	4.55	7.03	23.32
2010	0.89	1.17	1.24	2.45	1.54	6.71	3.86	4.55	5.14	18.48
2011	0.97	1.19	1.28	2.29	1.58	5.59	4.04	4.45	4.59	16.82
2012	1.02	1.29	1.37	2.26	1.60	5.27	3.75	4.39	4.50	16.18
2013	1.10	1.39	1.47	2.32	1.65	5.16	2.80	4.01	4.17	17.40
2014	1.04	1.33	1.39	2.07	1.52	4.47	3.01	3.74	3.83	17.73
2015	1.18	1.42	1.47	1.89	1.53	4.48	3.57	3.78	3.90	17.44
2016	1.47	1.76	1.86	2.13	1.83	4.94	4.07	4.21	4.32	16.86
2017	1.61	1.97	2.08	2.22	2.05	5.44	3.52	4.15	4.53	15.86

[a]Percentages are NR for these birth years because rotavirus and hepatitis A vaccines were not routinely administered across all Vaccine Safety Datalink sites until the birth year 2007.

DTaP, diphtheria–tetanus toxoids and acellular pertussis; Hib, *Haemophilus influenzae* type-b conjugate vaccine; MMR, measles, mumps, and rubella; NR, not reported; PCV, pneumococcal conjugate vaccine.

Table 3.

Parents' Degree of Vaccine Hesitancy, as Measured by the PACV[38,39] Scale

Question	ADU=0[a]	ADU Quintile 1 (ADU 0.1–9.0)	ADU Quintile 2 (ADU 9.1–21.3)	ADU Quintile 3 (ADU 21.4–60.7)	ADU Quintile 4 (ADU 60.8–205.4)	ADU Quintile 5 (ADU 205.5–457.0)
Degree of vaccine hesitancy (5-item PACVscale)[b,c]						
No hesitance (score=0)	19.8 (16.0, 23.7)	13.5 (9.7,17.2)	9.5 (0, 19.5)	5.6 (0, 12.4)	6.9 (2.1, 11.7)	6.8 (0,17.1)
Low hesitance (score=1–4)	63.6 (60.0, 67.2)	61.1 (56.7, 65.5)	51.9 (40.7, 63.2)	52.1 (46.0, 58.2)	55.3 (49.6, 61.1)	21.9 (6.3, 37.5)
Medium hesitance (score=5–6)	10.8 (6.4, 15.2)	12.0 (4.5,19.6)	23.9 (16.4, 31.5)	14.3 (6.0, 22.6)	18.6 (11.9, 25.3)	14.8 (10.2, 19.4)
High hesitance (score>6)	5.8 (3.7, 7.8)	13.4 (8.7,18.1)	14.6 (8.8, 20.5)	27.9 (16.7, 39.1)	19.1 (13.7, 24.4)	56.5 (45.4, 67.5)

[a] Average days undervaccinated was assessed at age 18 months for the survey cohort.

[b] Numbers represent the weighted %, with corresponding 95% CIs in parentheses.

[c] The 5-item PACV included questions about vaccine safety, efficacy, and overall concern, with 3 answer choices (*yes, don't know, no*); each answer was scored 0, 1, or 2 points, scores were summed across items, and the total score ranging from 0 to 10 was used to assign the degree of vaccine hesitancy.

ADU, average days undervaccinated; PACV, Parent Attitudes about Childhood Vaccines.