

Tetanus Toxoid, Reduced Diphtheria Toxoid, and Acellular Pertussis (Tdap) Vaccine Compliance Among Adolescents in the United States, 2010-2012

Samantha K Kurosky,¹ Keith L Davis,¹ Sudeep J Karve^{2*}

¹RTI Health Solutions, Research Triangle Park, NC, United States; ²AstraZeneca, Gaithersburg, MD, United States

BACKGROUND

- Pertussis, a highly communicable respiratory illness caused by the bacteria *Bordetella pertussis*, is often characterized by a prolonged paroxysmal cough and inspiratory whoop.
- Disease severity decreases with age and acquired immunity levels (i.e., prior infection and vaccination); therefore, young children are at the greatest risk for severe pertussis-related morbidity and mortality.¹
- The primary method of pertussis prevention is vaccination with an acellular pertussis-containing vaccine.
- Table 1 shows the vaccination schedule recommended for children by the Advisory Committee on Immunization Practices (ACIP).

Table 1. Summary of Pertussis Vaccination Recommendations

Age	Recommendation
< 2 years	DTaP primary series at 2, 4, and 6 months; single dose at 15 through 18 months
4-6 years	Single DTaP dose
7-10 years	Single Tdap dose for children who are not fully vaccinated with DTaP
11-12 years	Single Tdap dose If Tdap was received between ages 7 and 10 years, a dose should not be administered at ages 11 through 12 years
13-18 years	Catch-up ages for children who have not received Tdap

DTaP = diphtheria, tetanus toxoids, and acellular pertussis vaccine.

- Despite recommendations for routine vaccination, pertussis is endemic in the United States (US). In 2012, more than 48,000 cases of pertussis (15.2 per 100,000) were reported to the Centers for Disease Control and Prevention, an approximate 160% increase from 2011.²
- Incidence was highest among children aged 7 through 10 years (58.5 per 100,000), followed by children aged 11 through 19 years (38.0 per 100,000).
- Evidence suggests waning immunity among adolescents is one catalyst for the spread of disease.^{3,4} Although 89% of adolescents received tetanus, diphtheria (Td)/Tdap vaccine in 2012,⁵ little is known of the coverage of pertussis-containing vaccination specifically, or if Tdap is administered at the optimal ages (11 through 12 years).

OBJECTIVES

- The primary aim of this study was to evaluate compliance with ACIP recommendations for receipt of Tdap vaccination among adolescents in the US between 2010 and 2012.
- Specifically, the main objectives were as follows:
 - Estimate the proportion of adolescents who received at least one dose of Tdap by age 18 years.
 - Assess timeliness (vaccine administration at ages 11 through 12 years) of the first dose among adolescents who received Tdap.
 - Identify individual, household, and immunization provider characteristics associated with receipt and timeliness of Tdap vaccination.

METHODS

National Immunization Survey

- We analyzed data from the 2010, 2011, and 2012 National Immunization Survey-Teen (NIS-Teen).
- The NIS-Teen is a population-based random-digit-dial telephone survey of parents/guardians of children aged 13 through 17 years in the US.
- Respondents provided information on their child's demographic and household characteristics through a household survey.
- The child's health care providers reported vaccination histories as recorded in the child's medical chart.

Sample

- Aged 13 through 17 years at the time of the household survey
- Lived in the US (excluding US Virgin Islands)
- Completed the household survey
- Had adequate vaccination provider data
- Reported having at least one vaccination provider

Outcomes

Completion

- Children who received at least one dose of Tdap by age 18 years were considered complete based on ACIP guidelines.
- Completion rates were calculated as the proportion of adolescents who received Tdap among all adolescents in the sample.

Timeliness

- Although all adolescents who receive at least one dose of Tdap between the ages of 7 and 18 years were considered complete, the ACIP indicates that the optimal age range for administration of Tdap is 11 through 12 years.
- Therefore, timeliness was defined as Tdap administration at the earliest recommended age range, 11 through 12 years.
- Vaccine delay was defined as receipt of Tdap at ages 13 through 18 years.

Statistical Analysis

- Children fitting the inclusions criteria were selected from each of the three survey years.
- The first Tdap vaccine received between ages 7 and 18 years was selected for analysis. Tdap vaccines administered between ages 0 to 6 years were considered invalid and excluded from analysis.
- Weighted means and percentages were estimated using survey procedures, which account for the complex survey design of the NIS-Teen.
- Differences in the various measures were descriptively tested using t-tests for continuous variables and chi-square tests for categorical variables.
- Multivariable logistic regression was conducted to identify household and provider characteristics associated with two binary outcomes:
 - Completion: Received at least one Tdap vaccination between ages 7 and 18 years versus none.
 - Timeliness: Received at least one Tdap vaccination between ages 11 and 12 years versus received at least one Tdap vaccination between ages 13 and 18 years. Children who received Tdap between ages 7 and 10 years were excluded from analysis.

RESULTS

Demographics

- A weighted total of 62,240,880 children fitting the inclusion criteria were selected from the 2010, 2011, and 2012 NIS-Teen samples. Table 2 describes weighted sample characteristics.
 - Poverty status varied by year, with significant decreases observed between 2010 and 2011, and 2011 and 2012 ($P < 0.05$).
 - A greater proportion of mothers were younger in 2011 compared with 2010 ($P < 0.05$); other characteristics did not differ significantly.
 - The proportion of children who had an adolescent well-child visit and the number of immunization providers increased between 2011 and 2012 ($P < 0.05$).

Table 2. Household and Provider Characteristics

Characteristic	2010		2011		2012	
	n	%	n	%	n	%
Total population	20,551,354	100.00	20,913,984	100.00	20,775,542	100.00
Mother's age^a						
≤ 44 years	10,844,831	52.77	11,656,785	55.74	11,702,525	56.33
≥ 45 years	9,706,523	47.23	9,257,199	44.26	9,073,017	43.67
Mother's education						
High school or less	8,265,999	40.22	8,179,072	39.11	8,079,949	38.89
More than high school	12,285,355	59.78	12,734,912	60.89	12,695,594	61.11
Poverty status^{a,b}						
Below poverty level	3,977,424	19.35	4,716,399	22.55	5,299,786	25.51
Above poverty level	15,384,568	74.86	15,253,737	72.94	14,576,927	70.16
Unknown	1,189,362	5.79	943,848	4.51	898,829	4.33
Had an adolescent well-child visit^a						
No	1,410,979	6.87	1,456,367	6.96	68,250	5.82
Yes	14,978,376	72.88	15,447,519	73.86	231,588	75.46
Unknown	4,162,000	20.25	4,010,099	19.17	115,309	18.72
Number of providers^b						
1	10,060,974	48.96	10,466,542	50.05	9,858,916	47.45
2	10,490,381	51.04	10,447,442	49.95	10,916,626	52.55
Gap in health insurance coverage						
No	17,223,450	83.81	17,421,720	83.30	17,449,956	83.99
Yes	1,541,062	7.50	1,769,697	8.46	1,579,588	7.60
Unknown	1,786,842	8.69	1,722,567	8.24	1,745,998	8.40

Note: Reported counts and percentages are weighted.

^a Chi-square comparison between 2010 and 2011 was significant at $P < 0.05$.

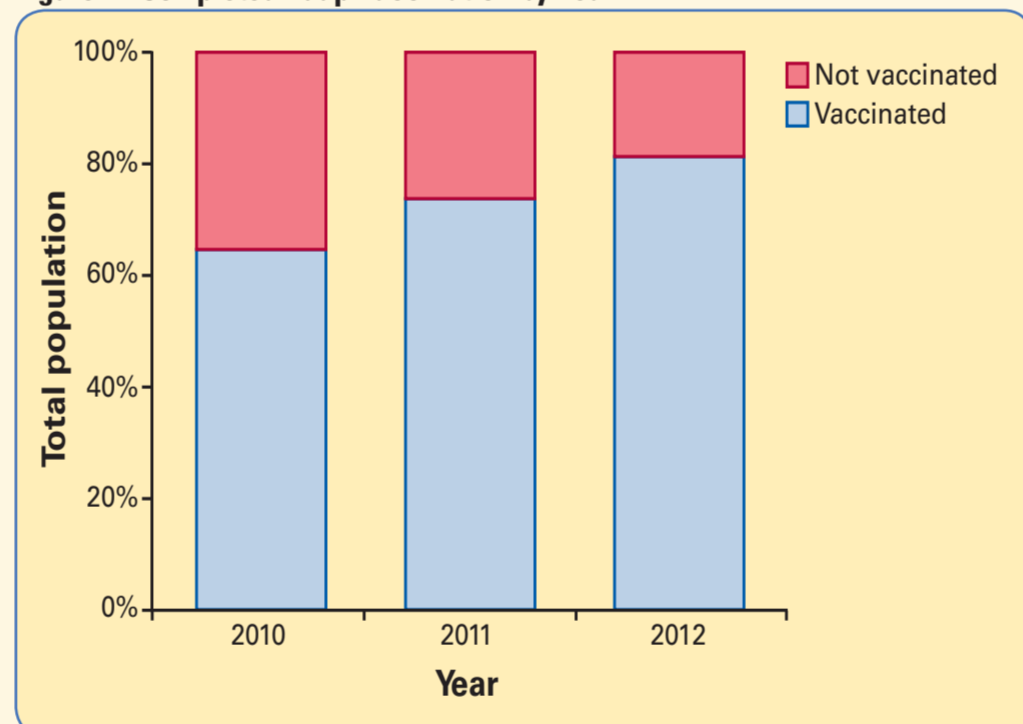
^b Chi-square comparison between 2011 and 2012 was significant at $P < 0.05$.

Outcomes

Completion

- Figure 1 displays the change in Tdap coverage between 2010 and 2012.
 - In 2010, 64.50% of adolescents received their first Tdap vaccine between the ages of 7 and 18 years.
 - This proportion increased significantly to 74.14% in 2011 and again to 81.30% in 2012 ($P < 0.05$).

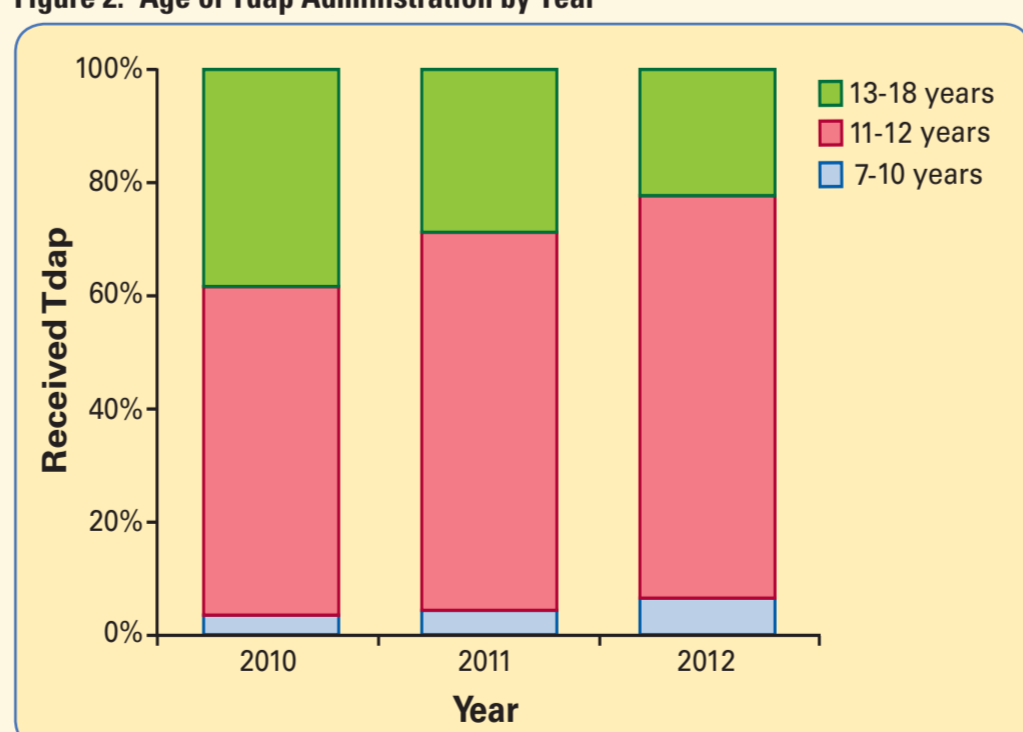
Figure 1. Completed Tdap Vaccination by Year



Timeliness

- Figure 2 displays the change in the distribution of age of Tdap administration between 2010 and 2012.
 - In 2010, 58.11% of adolescents received their first Tdap vaccine at the earliest recommended ages (11 through 12 years). This proportion increased significantly to 66.75% in 2011 and again to 71.55% in 2012 ($P < 0.05$).
 - The proportion of adolescents who delayed their first Tdap vaccination to between ages 13 to 18 years decreased from 38.29% in 2010 to 22.00% in 2012.
 - Among those who delayed vaccination, the mean age of vaccination was approximately 14 years in all three years.
 - Between 2010 and 2012, the proportion of children who received Tdap between the ages of 7 and 10 years increased from 3.60% to 6.45% ($P < 0.05$).

Figure 2. Age of Tdap Administration by Year



Multivariable Analysis (Table 3)

Model 1: Received Tdap Vaccination

- A higher level of mother's education and living in a household above the federal poverty level were significantly associated with an increased likelihood of receipt of Tdap vaccination between 7 and 18 years of age.
- Having a mother over age 45, no adolescent well-child visit, more than one immunization provider, and a gap in health insurance coverage were associated with a decrease in completion.

Model 2: Tdap Administered at Ages 11 Through 12

- A higher level of mother's education and living in a household above the federal poverty level were significantly associated with an increased likelihood of receipt of Tdap at ages 11 through 12 years, compared with receipt at ages 13 through 18 years.
- Having a mother over age 45, no adolescent well-child visit, more than one immunization provider, and a gap in health insurance coverage were associated with delaying vaccination.

Table 3. Adjusted Odds of Tdap Receipt at Age-Appropriate Times

Characteristic	Model 1 (Completion): Received Tdap Ages 7-18 Years			Model 2 (Timeliness): Received Tdap Ages 11-12 Years		
	Adj. OR	95% CI	P Value	Adj. OR	95% CI	P Value
NIS year						
2010 (ref)						
2011	1.60	1.48-1.73	< .0001	1.60	1.45-1.77	< .0001
2012	2.45	2.23-2.68	< .0001	2.17	1.94-2.43	< .0001
Mother's age						
≤ 44 years (ref)						
≥ 45 years	0.91	0.86-0.97	0.0015	0.86	0.80-0.92	< .0001
Mother's education						
High school or less (ref)						
More than high school	1.11	1.07-1.15	< .0001	1.18	1.12-1.24	< .0001
Poverty status						
Below poverty level (ref)						
Above poverty level	1.13	1.02-1.26	0.0212	1.27	1.11-1.44	0.0005
Had an adolescent well-child visit						
Yes (ref)						
No	0.69	0.59-0.80	< .0001	0.44	0.37-0.52	< .0001
Unknown	0.99	0.90-1.08	0.8246	2.79	2.44-3.20	< .0001
Number of providers						
1 (ref)						
2 or more	0.85	0.80-0.91	< .0001	0.78	0.71-0.85	< .0001
Gap in health insurance coverage						
No (ref)						
Yes	0.86	0.76-0.98	0.0203	0.75	0.64-0.87	0.0002

Adj. OR = adjusted odds ratio; CI = confidence interval.

DISCUSSION

- Vaccinating adolescents is a challenging task due to low rates of physician office visits, difficulty perceiving susceptibility to disease, lack of parental consent, and out-of-pocket vaccination costs.⁶ Nonetheless, the present study found receipt of Tdap vaccination increased over 16 percentage points between 2010 and 2012, indicating that acceptance of and accessibility to the vaccine may be increasing.
- Tdap is administered between the ages of 7 and 10 years for children who did not complete five doses of DTaP. Therefore, the increase in Tdap receipt between ages 7 and 10 years indirectly suggests pertussis susceptibility during infancy due to incomplete DTaP vaccination.
- In the present study, we found a 13 percentage point increase in receipt of Tdap at the recommended ages (11 through 12 years) during the study period. This increase in Tdap at recommended ages may contribute to an increase in sustained immunity levels during a time where pertussis immunity may begin to wane.
- Despite the increase in timely vaccination, nearly one in four adolescents delayed Tdap vaccination. Furthermore, those who delayed vaccination received it an average of 1 year late (age 14 years).
- Interventions to increase Tdap vaccination among adolescents should incorporate strategies to increase adolescent well-child visits, improve the medical home, and reduce gaps in health insurance coverage.

CONCLUSIONS

- Although Tdap coverage rates exceeded national goals in 2012, focusing only on receipt of vaccination by age 18 years fails to detect the numerous children who delayed vaccination.
- Examining the age-appropriate receipt of Tdap provides a more detailed description of pertussis susceptibility during adolescence, a time when waning immunity is dependent on age and previous pertussis immunity level.

REFERENCES

- CDC. Manual for the surveillance of vaccine-preventable diseases. Roush SW, McIntyre L, Balducci LM, eds. 5th ed. Atlanta: CDC; 2012.
- CDC. 2012 final pertussis surveillance report. Updated October 18, 2013. Available at: <http://www.cdc.gov/pertussis/downloads/pertussis-surveillance-report.pdf>. Accessed November 25, 2013.
- Lavine J, Broutin H, Harville ET, Bjornstad ON. Imperfect vaccine-induced immunity and whooping cough transmission to infants. Vaccine 2010;29(1):11-6.
- Wendelboe AM, Van Rie A, Salmaso S, Englund JA. Duration of immunity against pertussis after natural infection or vaccination. 2005;24(5 Suppl):S58-61.
- CDC. National and state vaccination coverage among adolescents aged 13-17 years—United States, 2012. MMWR 2013;62(34):685-93.
- Humiston SG, Rosenthal SL. Challenges to vaccinating adolescents: Vaccine implementation issues. Pediatr Infect Dis J. 2005;24(6 Suppl):S134-40.

CONTACT INFORMATION

Samantha K Kurosky, MSPH
Senior Health Outcomes Scientist

RTI Health Solutions
300 Park Offices Drive
Research Triangle Park, NC 27709

Phone: +1.919.541.7164
Fax: +1.919.541.7222
E-mail: skurosky@rti.org

Presented at: ISPOR 19th Annual International Meeting
May 31-June 4, 2014
Montreal, QC, Canada

* Dr. Karve was an employee of RTI Health Solutions when this work was completed.

