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Tdap Vaccination Among Healthcare Personnel, Internet Panel Survey, 2012–2014

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Abstract

Introduction—Healthcare personnel (HCP) are at risk for pertussis infection exposure or transmitting the disease to patients in their work settings. The Advisory Committee on Immunization Practices recommends tetanus toxoid, reduced diphtheria toxoid, and acellular pertussis (Tdap) vaccination for HCP to minimize these risks. This study assessed Tdap vaccination coverage among U.S. HCP by sociodemographic and occupation-related characteristics.

Methods—The 2012, 2013, and 2014 Internet Panel Surveys were analyzed in 2015 to assess HCP Tdap vaccination. Effective sample sizes for 2012, 2013, and 2014 survey years were 2,038, 1613, and 1633, respectively. Missing values were assigned using multiple imputation. Multivariable logistic regression identified factors independently associated with HCP Tdap vaccination. Statistical measures were calculated with an assumption of random sampling.

Results—Overall, Tdap vaccination coverage among HCP was 34.8% (95% CI=30.6%, 39.0%); 40.2% (95% CI=36.1%, 44.4%); and 42.4% (95% CI=38.7%, 46.0%) in 2012, 2013, and 2014, respectively. Nurse practitioners/physician's assistants, physicians, nurses, and HCP working in hospitals and ambulatory care settings had higher Tdap coverage. Having contact with an infant aged ≤6 months and influenza vaccination receipt were associated with increased Tdap vaccination. Non-Hispanic black race/ethnicity, having an associate/bachelor's degree, being below poverty, non-clinical personnel status, and working in a long-term care setting were associated with decreased Tdap vaccination.

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Conclusions—HCP Tdap vaccination coverage increased during 2012–2014; however, coverage remains low. Vaccination coverage varied widely by healthcare occupation, occupational setting, and sociodemographic characteristics. Evidence-based employer strategies used to increase HCP influenza vaccination, if applied to Tdap, may increase Tdap coverage.

INTRODUCTION

Healthcare personnel (HCP) are at risk for exposure to and possible transmission of pertussis, a vaccine-preventable disease, in their occupational settings because of their contact with patients or respiratory secretions from patients.[1–3] In several pertussis outbreaks in healthcare settings, HCP have been exposed to pertussis by other HCP, patients, and hospital visitors.[4–8] Vaccinating HCP is one of the main strategies to protect them and prevent transmission of pertussis.[9,10] The risk of pertussis among HCP is 1.7 times higher than that of the general adult population.[11] To prevent pertussis in healthcare settings, the Advisory Committee on Immunization Practices recommended in 2005 that HCP aged <65 years receive a single dose of tetanus toxoid, reduced diphtheria toxoid, and acellular pertussis (Tdap) vaccine at an interval as short as 2 years from the last dose of tetanus and diphtheria toxoids (Td).[12] In 2011, the Advisory Committee on Immunization Practices revised and expanded the HCP Tdap recommendations to all HCP, regardless of age and time since their most recent Td vaccination.[1] Hospital-based Tdap uptake among HCP has depended on the institution's Tdap vaccination program; coverage rates range from 30% (campaign) to 100% (hospital mandate).[13,14] Recent nationally reported Tdap coverage among HCP is 42.1%.[15]

Studies regarding Tdap vaccination among HCP have reported on overall coverage and coverage by occupation,[15–18] with limited reports of Tdap vaccination among HCP by occupational setting.[19] The objective of this study was to assess Tdap vaccination coverage and identify factors independently associated with vaccination among HCP by sociodemographic and employment factors, including occupation and occupational setting.

METHODS

Study Sample

The 2012, 2013, and 2014 Internet Panel Survey data were analyzed in 2015. The Internet Panel Survey is an opt-in web-based non-probability survey conducted by Abt Associates Inc. for the Centers for Disease Control and Prevention (CDC), which collects health information on the U.S. HCP population. HCP were eligible for the surveys if they reported working in a healthcare setting or having any patient contact.

Professional HCP (physicians, physician assistants [PAs], nurse practitioners [NPs], nurses, dentists, pharmacists, allied health professionals, technicians, and technologists) were recruited from the current membership roster of Medscape, a medical website managed by WebMD Health Professional Network. Individuals in additional HCP occupations (assistants, aides, administrators, clerical support workers, janitors, food service workers, and housekeepers) were recruited for a health survey from SurveySpot, a general population Internet panel that provides members with online survey opportunities in exchange for

nominal incentives. The same methodology was used in all 3 survey years. Among eligible respondents who started the survey, the survey completion rate was 93.2%, 95.5%, and 94.9% for 2012, 2013, and 2014 surveys, respectively.

Measures

This study assessed Tdap vaccination. To determine Tdap vaccination status, respondents were asked the following question: *Have you received a tetanus vaccine in the past 10 years?* An affirmative answer to the tetanus vaccination question prompted a second question about the recency of the tetanus vaccination: *Was your most recent tetanus vaccine given in 2005 or later?* An affirmative answer to this question prompted a question about the type of tetanus vaccination: *Thinking back to your most recent tetanus vaccination, which vaccine were you given, the Td or tetanus–diphtheria vaccine or the Tdap, also known as Adacel™ or Boostrix™ (which includes the pertussis or whooping cough vaccine)?*

Statistical Analysis

Point estimates and 95% CIs of vaccination coverage were calculated using SAS, version 9.3, and SUDAAN, version 11.01. Data were weighted by age, sex, race/ethnicity, occupational setting, and Census region based on each occupation type to reflect the U.S. HCP population. Two-tailed chi-square tests were used to check for associations with significance level set at $p < 0.05$. Multivariable logistic and predictive marginal models were conducted to derive adjusted vaccination coverage and prevalence ratios to identify factors independently associated with Tdap vaccination. Poverty status was defined based on the reported number of people and children living in the household and annual household income, and the U.S. Census poverty thresholds (www.census.gov/data/tables/time-series/demo/income-poverty/historical-poverty-thresholds.html). Statistical measures were calculated with an assumption of random sampling and should be interpreted only as guides to assessing the associations from this non-probability sample.

Missing data for Tdap vaccination status for respondents who answered that they were vaccinated with tetanus vaccine since 2005 but either were not told by their doctor or were not sure which type of tetanus vaccine they received were imputed using multiple imputation under the missing at random assumption.[20] Details of item-level missingness of Tdap vaccination status in the cascade of questions used to ascertain the vaccination status and the effective sample size for the study population (which excluded those respondents who were missing for questions *Have you received a tetanus vaccine in the past 10 years? and Was your most recent tetanus vaccine given in 2005 or later?*) are presented in Table 1. Tdap vaccination status was imputed only for those missing the type of tetanus booster received (respondents who either were not told by their doctor the type of tetanus vaccine [Td or Tdap] they received or were not sure which type of tetanus vaccine they received) and the percentage of respondents with this missing data was 23.8%, 21.8%, and 26.3% for the 2012, 2013, and 2014 surveys, respectively. Other variables with missing data, such as poverty, employment status, employer policy for influenza vaccination, age, contact with an infant aged ≤6 months, occupation, and occupational setting, were also imputed using this method. Estimates of Tdap vaccination were calculated with the multiply imputed data.

Imputations were done using the logistic regression fractional conditional specification multiple imputation method.[21] The SAS MI procedure was used to generate ten imputed data sets (relative efficiency rate, 97%).[22] The results from the ten data sets were combined for overall inferences, accounting for variability between imputations by modifying the SAS macro procedure as described elsewhere.[23]

A sensitivity analysis was also conducted to assess the magnitude of potential recall bias by examining the impact of missing Tdap vaccination status on the overall Tdap coverage estimates. For the sensitivity calculations, all excluded respondents (those who answered *my doctor did not say* or *not sure* to the question about the type of the tetanus vaccination received) were assumed to be either not vaccinated or vaccinated with Tdap vaccination. Both pre- and post-imputation overall Tdap coverage estimates are reported. Proportions of HCP surveyed in 2012, 2013, and 2014 who reported receiving Tdap were estimated, and a test for linear trend by survey year was performed in SUDAAN using the RATIO procedure. Where not specifically mentioned, the results refer to estimates obtained post-imputation only. The Internet Panel Survey was designated as non-research by the review boards of CDC and Abt Associates Inc., and was exempt from IRB review.

RESULTS

A total of 2,353, 1,944, and 1,883 respondents from the 2012, 2013, and 2014 surveys, respectively, were included in the study. For primary analysis with imputed Tdap status, the effective sample sizes were 2,038, 1,613, and 1,633 for 2012, 2013, and 2014 surveys, respectively (Table 1).

The demographic characteristics of the samples and Tdap coverage by survey year are shown in Table 2. In all years, the largest proportions of HCP were aged 18–49 years, non-Hispanic white, had associate/bachelor's degree, were above poverty, worked as other clinical personnel, worked in a hospital, did not have contact with an infant aged ≤6 months, worked as a direct hire, and received influenza vaccination in the current influenza season (Table 2).

Pre-imputation Tdap coverage was 36.1% in 2012, 40.9% in 2013, and 44.3% in 2014 (data not shown). Tdap coverage post-imputation was 34.8% in 2012, 40.2% in 2013, and 42.4% in 2014 (Table 2). Overall, Tdap coverage among HCP increased from 34.8% in 2012 to 42.4% in 2014 (test for trend, p=0.0031). In all survey years, coverage was higher among physicians, NPs/PAs, and nurses compared with other clinical personnel and non-clinical personnel (Table 2). By occupational group, the smallest increases in coverage from 2012 to 2014 were observed among non-clinical personnel and other clinical personnel. The largest increase was seen among nurses, whose coverage increased from 48.1% in 2012 to 63.8% in 2014 (Table 2), followed by NPs/PAs and physicians. In all survey years, coverage among HCP working in long-term care (LTC) settings was lower than among those working in hospitals or outpatient settings (Table 2). By occupational setting, the largest increase was observed within hospitals, where coverage increased from 35.7% in 2012 to 53.1% in 2014. Coverage remained stable from 2012 to 2014 among HCP working in ambulatory care settings (40.2% and 41.1% in 2012 and 2014, respectively) and LTC settings (20.9% and

22.9% in 2012 and 2014, respectively). Among HCP working in other healthcare settings, coverage decreased from 40.9% in 2012 to 30.9% in 2013, and then increased to 54.7% in 2014 (Table 2).

Non-clinical personnel had a decreased likelihood of Tdap vaccination compared with physicians in all survey years, and working in an LTC setting was associated with decreased likelihood of vaccination in 2 survey years (Table 3). Factors associated with decreased likelihood of vaccination in at least 1 of 3 survey years included non-Hispanic black race/ethnicity, having associate/bachelor's degree, and living below poverty. Having contact with an infant aged ≤6 months was associated with increased likelihood of Tdap vaccination in 2 survey years, and receipt of influenza vaccination was associated with increased likelihood of Tdap vaccination in 1 survey year (Table 3).

Sensitivity analyses varying proportions of respondents with missing Tdap vaccination status showed actual Tdap coverage could fall within the range of 25.9%–52.1% for 2012 survey year, 30.1%–55.2% for 2013 survey year, and 31.7%–59.6% for 2014 survey year (Table 4).

DISCUSSION

In 2012, 2013, and 2014, Tdap vaccination coverage was 35%, 40%, and 42%, respectively. Coverage varied widely by occupation type, occupational setting, sociodemographic, and other employment-related characteristics. Though an increase in Tdap coverage over survey years was observed in this study, Tdap coverage among HCP remained low. Increasing Tdap vaccination among HCP is crucial to minimize risk of pertussis transmission in healthcare settings.

In 2012–2014, Tdap coverage increased in all occupational groups, with the smallest increase in coverage observed among other clinical and non-clinical personnel, groups that also had lower coverage. Overall Tdap coverage estimates among HCP in 2012 and 2014 were similar to that reported from the nationally representative National Health Interview Survey (NHIS).[15,17] Higher coverage was found among NPs/PAs, physicians, and nurses. The variability in Tdap coverage by HCP occupation type observed in this study was similar to variation in Tdap coverage by occupation type reported previously,[19] but unlike differences in coverage observed between physicians, nurses, and other types of HCP in the NHIS study,[19] coverage was similar among these occupation groups in this study. The estimates found in this study were higher compared with NHIS-estimated[19] Tdap coverage among HCP. The higher point estimates in this study might be due to differences in sampling design, mode of the surveys, or other survey attributes. Although Tdap coverage among U.S. HCP remains suboptimal, yearly increases in coverage as observed in this study are nonetheless encouraging. Lower awareness of Tdap vaccine,[24] lower intent among all HCP occupational groups to receive Tdap vaccine,[25] and confusion about the interval to receive Tdap after receipt of the last Td vaccination[19] have been reported as potential barriers to uptake of Tdap vaccination.

This is the first report of Tdap coverage among HCP by occupational setting. By occupational setting, the lowest coverage was observed among HCP working in LTC settings and the highest coverage was found among HCP working in hospitals for all 3 years, similar to patterns in influenza vaccination among HCP by occupational setting.[26] Higher coverage among HCP working in hospital settings could be attributable to policies requiring HCP to receive Tdap vaccination, such as making employment conditional upon receipt of Tdap vaccine for new employees and setting a termination date for noncompliance among current employees, policies that have been shown to increase vaccination levels.[14] Approximately 31% of U.S. hospitals had requirements for HCP to receive Tdap vaccine in 2011.[27] Although there were no estimates available for the frequency of requirements or other policies for Tdap vaccination in LTC settings, requirements for and promotion of influenza vaccination have been reported to be less common in LTC settings compared with hospitals.[26] No increase in Tdap coverage was observed in LTC settings during the 3 years of the survey.

Characteristics associated with an increased likelihood of Tdap vaccination among HCP were having contact with an infant aged ≤6 months and receipt of influenza vaccination for the current season. Receipt of influenza vaccination in the previous season has been reported to be associated with increased Tdap vaccination among HCP[19] and may suggest that strategies used to increase influenza vaccination among HCP could be beneficial in improving Tdap coverage. Despite Tdap vaccination being strongly recommended for HCP with any direct patient contact either in a hospital or clinic setting,[1] intent to vaccinate and acceptance of pertussis vaccine[18] and use of Tdap vaccines by HCP has been low,[15,16,19] and the implementation of immunization recommendations by healthcare institutions has been suboptimal.[28] The association between having contact with an infant aged ≤6 months and increased likelihood of Tdap vaccination is likely due to the separate recommendation for Tdap vaccination as a cocooning strategy for prevention of pertussis in infants.[29]

Studies report that access to influenza vaccination at the worksite is associated with higher influenza coverage among HCP.[30] Studies have also shown that HCP working in LTC settings were more likely to report that their employer neither required, provided, nor promoted influenza vaccination compared with HCP working in other occupational settings.[26] In addition, HCP working in LTC settings have had the lowest reported influenza coverage compared with HCP working in other occupational settings.[26,30] These findings indicate that employer support for worksite influenza vaccination activities is associated with higher likelihood that personnel will be vaccinated. Poor support of vaccination activities by LTC employers may help explain why a decreased likelihood of Tdap vaccination among HCP working in LTC settings was observed in the current study.

Another study using NHIS data reported that non-Hispanic black HCP with direct patient care responsibilities had lower Tdap coverage than non-Hispanic white HCP.[15] A similar finding was reported in the current study, where non-Hispanic black HCP had decreased likelihood of Tdap vaccination. These findings suggest that racial/ethnic disparities still persist for routinely recommended vaccines, even among HCP. Racial/ethnic disparities in vaccination coverage among adults are multifactorial, involving patient-, provider-, and system-related factors, including differences in attitudes toward vaccination and preventive

care, propensity to seek or accept vaccination, differences by occupation and occupational settings, differences in the quality of care received by racial/ethnic minorities,[15,31–35] and inconsistent adoption of the standards for adult vaccination practices.[36]

Though no studies have investigated strategies other than vaccination requirements to increase Tdap coverage, many studies have investigated the effects of employer policies in improving influenza coverage among HCP. Increasing awareness among HCP about the benefits of influenza vaccination with comprehensive employer vaccination programs such as convenient access to vaccination services and providing influenza vaccination at no charge[1,37] have been shown to be associated with increased vaccination coverage. Similar policies implemented for Tdap vaccination may help improve Tdap coverage among HCP.

Limitations

The primary limitation of this study is the use of statistics with a non-probability sample—estimates of sampling error are usually not computed.[38] The sample was not randomly selected from the U.S. HCP population, but consisted of a nonprobability sample of volunteer HCP members of the Medscape and Survey-Spot Internet panels who self-selected to participate in these panels. Estimates of coverage may be biased if the selection processes for entry into the Internet panel and a survey participant's decision to participate in the survey were related to receipt of vaccination. The statistical measures of association presented here should be taken only as a guide to assessing value of the associations from this non-probability sample. Overall Tdap coverage estimates among HCP in 2012 and 2014, however, were similar to that reported from the nationally representative NHIS.[15,17] Second, the results based on these non-probability samples might not be representative of the U.S. HCP population as non-coverage and non-response bias may still remain even after weighting adjustments. Vaccination status was self-reported, not verified by employment or medical records, and might be subject to recall and misclassification bias. A recent study assessing the ability of healthcare workers to recall previous receipt of tetanus-containing vaccination and validating the self-report with their electronic medical record found high concordance between self-report and electronic medical record regarding their tetanus vaccination history within previous 2 years or more than 2 years earlier.[39] However, in this study and in a previous study, even when HCP knew if they received a tetanus-containing vaccine, many did not know if it was Td or Tdap.[19] Sensitivity analysis revealed that Tdap coverage estimates could have varied by approximately 20 percentage points depending on the number of excluded respondents with missing vaccination information that actually received Tdap. Finally, imputing for missing data may produce biased estimates, which depend upon the missingness pattern of the data and the analytic method used to impute missing data.[40–42] Though it is impossible to know the actual reasons for all missing data, sensitivity analyses can provide a test of whether the assumptions of missing completely at random, missing at random, or missing not at random conditions are likely for a given set of analyses.[42]

CONCLUSIONS

This study indicates that, despite Advisory Committee on Immunization Practices recommendations for Tdap vaccination since 2006 and availability of safe and effective vaccines, Tdap coverage among HCP remains low, particularly among other clinical and non-clinical personnel and HCP working in LTC settings. Comprehensive strategies by healthcare facilities are needed to increase overall vaccination coverage. Strategies that may help in improving uptake of Tdap vaccination and other recommended vaccinations for HCP include targeting intervention in areas where vaccination uptake is low; increasing awareness about potential effects of vaccination on overall HCP health, their patients, and their families along with the benefits of vaccination in reducing transmission of vaccine-preventable disease; providing vaccines at the workplace free or at reduced costs; and offering vaccines onsite or offsite, in clinics, or at multiple locations.[1,37]

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AS conceived the study, performed the statistical analysis, and wrote the first draft of the manuscript and led revisions of all subsequent versions. AS had access to all data and takes the responsibility for their integrity. JZ also contributed to the conception of the study, data analysis, and critical revision of the manuscript. CLB, PL, JLL, and SMG participated in data interpretation and revising of the manuscript. All authors have reviewed and approved the submitted version of the manuscript.

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Table 1

Tdap Vaccination Missing Status, Healthcare Personnel Internet Panel Survey, 2012–2014, U.S.

Survey questions	April 2012 Survey		April 2013 Survey		April 2014 Survey	
	Sample size, *n*	Missing (% missing)	Sample size, *n*	Missing (% missing)	Sample size, *n*	Missing (% missing)
Have you received a tetanus vaccine in the past 10 years?[a]	2,353	166 (7.1)	1,944	194 (10.0)	1,883	139 (7.4)
Was your most recent tetanus vaccine given in 2005 or later?[b]	1,861	149 (8.0)	1,486	137 (9.2)	1,505	111 (7.4)
Thinking back to your most recent tetanus vaccination, which vaccine were you given, the Td or tetanus-diphtheria vaccine or the Tdap, also known as Adacel or Boostrix (which includes the pertussis or whooping cough vaccine)?	1,459	348[c] (23.8)	1,197	260[c] (21.8)	1,296	302[c] (26.3)
Effective study population[d]	2,038		1,613		1,633	

[a] An affirmative answer to this question prompted a second question about the recency of the tetanus vaccination, *Was your most recent tetanus vaccine given in 2005 or later?*

[b] An affirmative answer to this question prompted a question about the type of tetanus vaccination, *Thinking back to your most recent tetanus vaccination, which vaccine were you given, the Td or tetanus-diphtheria vaccine or the Tdap, also known as Adacel or Boostrix (which includes the pertussis or whooping cough vaccine)?*

[c] All respondents (those who answered *my doctor did not say* or *not sure* to the question about the type of tetanus vaccination received) were assumed to be missing for Tdap vaccination status and were imputed using multiple imputation method.

[d] Effective study population excludes those respondents who were missing for questions *Have you received a tetanus vaccine in the past 10 years?* and *Was your most recent tetanus vaccine given in 2005 or later?*

Tdap, tetanus toxoid, reduced diphtheria toxoid, and acellular pertussis vaccine.

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Table 2

Sociodemographic and Occupation-Related Characteristics of Study Population and Unadjusted Tdap Vaccination Coverage

Characteristics	2012			2013			2014		
	Sample size, *n*	Weighted %	Tdap vaccination coverage,[a] % (95% CI)	Sample size, *n*	Weighted %	Tdap vaccination coverage, % (95% CI)	Sample size, *n*	Weighted %	Tdap vaccination coverage, % (95% CI)
Overall	2,038	100.0	34.8 (30.6, 39.0)	1,613	100.0	40.2 (36.1, 44.4)	1,633	100.0	42.4 (38.7, 46.0)
Age group (years)									
18–49	1,097	62.4	38.5 (33.0, 44.0)	963	67.3	43.0 (37.8, 48.3)	968	66.4	43.3 (37.8, 48.2)
50–64	816	32.7	28.7 (22.6, 34.7)	596	28.8	36.3 (30.2, 42.4)	600	29.2	41.9 (35.6, 48.3)
≥65	125	4.9	28.6 (11.5, 45.7)	54	3.9	21.1 (5.4, 36.9)	65	4.4	30.5 (10.2, 50.8)
Race/ethnicity									
Non-Hispanic, white only	1,245	68.3	34.3 (29.3, 39.3)	1,010	67.2	40.5 (35.3, 45.7)	1,024	65.6	41.0 (36.4, 45.6)
Non-Hispanic, black only	296	13.7	29.6 (20.0, 39.1)	260	14.8	35.1 (24.9, 45.3)	214	13.5	39.0 (29.1, 48.9)
Hispanic	296	10.7	41.8 (31.4, 52.2)	229	12.8	41.0 (29.4, 52.7)	259	12.7	51.8 (41.1, 62.5)
Non-Hispanic, other or multiple races	201	7.3	38.9 (27.2, 50.7)	114	5.2	50.1 (33.9, 66.3)	137	8.2	44.0 (30.4, 57.6)
Educational status									
Some college education or less	376	31.3	22.1 (15.1, 29.0)	339	31.6	25.8 (18.2, 33.5)	335	28.3	26.5 (20.0, 33.0)
Associate/bachelor's degree	663	45.6	38.5 (32.1, 44.8)	596	48.8	43.0 (36.9, 49.2)	602	47.8	44.9 (39.0, 50.7)
Beyond college degree	999	23.1	44.9 (38.6, 51.2)	678	19.6	56.6 (50.5, 62.7)	696	23.9	56.2 (49.6, 62.8)
Poverty status[b]									
Below poverty	147	9.4	29.6 (16.2, 42.9)	78	5.5	28.1 (12.5, 43.7)	80	7.3	23.8 (9.5, 38.1)
Above poverty	1,891	90.6	35.3 (30.9, 39.7)	1,535	94.5	40.9 (36.7, 45.2)	1,553	92.7	43.8 (40.0, 47.6)

Characteristics	2012			2013			2014		
	Sample size, *n*	Weighted %	Tdap vaccination coverage,[a] % (95% CI)	Sample size, *n*	Weighted %	Tdap vaccination coverage, % (95% CI)	Sample size, *n*	Weighted %	Tdap vaccination coverage, % (95% CI)
Occupation categories									
Physician	383	4.3	50.9 (45.5, 56.4)	285	4.7	60.1 (53.9, 66.4)	290	4.3	60.7 (54.5, 67.0)
Nurse practitioner/physician assistant	142	1.3	58.5 (50.0, 66.9)	124	1.5	68.2 (59.7, 76.8)	120	1.0	69.6 (61.0, 78.3)
Nurse	334	22.1	48.1 (40.5, 55.7)	175	20.3	58.8 (50.1, 67.5)	199	21.3	63.8 (55.6, 71.9)
Other clinical personnel[c]	848	42.6	34.9 (28.9, 40.9)	682	44.9	37.0 (31.1, 42.9)	660	42.8	39.7 (33.9, 45.5)
Non-clinical personnel[d]	331	29.7	21.4 (12.9, 29.8)	347	28.5	27.3 (18.9, 35.8)	365	30.6	27.8 (21.6, 34.0)
Occupational settings									
Hospital	1,030	39.6	35.7 (29.5, 42.0)	808	39.1	52.8 (46.7, 58.8)	759	41.4	53.1 (47.4, 58.8)
Ambulatory care/physician's office	460	28.0	40.2 (32.4, 47.9)	368	28.2	41.1 (32.7, 49.5)	413	23.5	41.1 (32.1, 50.1)
Long-term care facility	323	19.2	20.9 (13.2, 28.7)	286	19.4	20.2 (12.8, 27.5)	258	26.6	22.9 (14.9, 30.8)
Other settings[e]	224	13.2	40.9 (29.4, 52.4)	151	13.3	30.9 (19.4, 42.4)	203	8.4	54.7 (42.0, 67.4)
Contact with an infant aged ≤6 months									
Yes	275	11.3	55.4 (44.9, 66.0)	234	12.4	53.5 (42.5, 64.5)	181	9.3	65.7 (55.0, 76.5)
No	1,763	88.7	32.2 (27.8, 36.6)	1,379	87.6	38.4 (34.0, 42.8)	1,453	90.7	40.0 (36.1, 43.9)
Employment									
Direct hire	1,506	81.6	35.5 (31.0, 40.0)	1,222	82.7	40.3 (35.5, 45.0)	1,234	81.5	43.6 (39.4, 47.7)
Licensed independent practitioner	243	5.4	33.9 (21.5, 46.4)	149	4.3	40.8 (27.7, 54.0)	171	6.4	47.5 (34.7, 60.3)
Contract employee	289	13.0	30.9 (20.2, 41.7)	242	13.0	39.9 (28.7, 51.1)	228	12.0	31.5 (20.9, 42.2)
Influenza vaccination in current season									

Characteristics	2012			2013			2014		
	Sample size, *n*	Weighted %	Tdap vaccination coverage,[a] % (95% CI)	Sample size, *n*	Weighted %	Tdap vaccination coverage, % (95% CI)	Sample size, *n*	Weighted %	Tdap vaccination coverage, % (95% CI)
Yes	1,556	66.8	42.2 (37.2, 47.2)	1,291	72.5	44.7 (40.1, 49.4)	1,343	75.5	48.0 (43.8, 52.2)
No	482	33.2	19.9 (13.5, 26.3)	322	27.5	28.4 (20.8, 36.0)	290	24.5	25.0 (17.3, 32.6)
Employer policy for flu vaccination									
Yes	1,165	49.9	40.4 (34.1, 46.6)	1,014	53.9	49.3 (43.6, 55.0)	1,149	66.9	49.5 (45.0, 53.9)
No	873	50.1	29.3 (23.9, 34.7)	599	46.1	29.7 (23.6, 35.9)	484	33.1	28.0 (21.6, 34.4)

[a]Missing data for Tdap vaccination status for respondents who answered that they were vaccinated with tetanus vaccine since 2005 but either were not told by their doctor or were not sure which type of tetanus vaccine they received were imputed using multiple imputation under the missing-at-random assumption. Other variables with missing data, such as poverty, employment status, employer policy for influenza vaccination, age, contact with an infant ≤6 months, occupation, and occupational setting, were also imputed using this method. Estimates of Tdap vaccination were calculated with imputed data when responses to one or more questions were unknown. Imputations were done using the logistic regression Fractional Conditional Specification multiple imputation method, with age group, race/ethnicity, education, poverty, occupation, occupational setting, contact with an infant ≤6 months, employment status, influenza vaccination status, and employer policy for influenza vaccination as predictors, generating 10 imputed data sets. Tdap vaccination coverage proportion was calculated for each imputed data set. The results from the 10 imputed data sets were combined for overall inferences, accounting for variability between imputations.

[b]Poverty status was defined based on the reported number of people and children living in the household and annual household income, and the U.S. Census poverty thresholds (www.census.gov/data/tables/time-series/demo/income-poverty/historical-poverty-thresholds.html). As determined by the U.S. Census Bureau, for the 2014–2015 season below poverty = total family income of <$24,008 for a family of four with two minors as of 2014; for the 2013–2014 season below poverty = total annual family income of <$23,624 for a family of four with two minors as of 2013; for the 2012–2013 season below poverty = total annual family income of <$23,283 for a family of four with two minors as of 2012.

[c]Allied health professionals, technicians, and technologists.

[d]Administrative support staff members or manager and nonclinical support staff members (including food service workers, laundry workers, janitors, and members of the housekeeping and maintenance staffs).

[e]Dentist office or dental clinic, pharmacy, laboratory, public health setting, healthcare education setting, emergency medical services setting, or other setting where clinical care or related services was provided to patients.

Tdap, tetanus toxoid, reduced diphtheria toxoid, and acellular pertussis vaccine.

Table 3

Tdap Vaccination and Multivariable Logistic Regression Analysis Among Healthcare Personnel, by Sociodemographic and Occupation-Related Characteristics

Characteristics	2012 APR[a] (95% CI)	2013 APR (95% CI)	2014 APR (95% CI)
Age group (years)			
18–49	1.40 (0.33, 2.47)	1.98 (0.57, 3.40)	1.45 (0.57, 2.33)
50–64	1.03 (0.29, 1.78)	1.54 (0.41, 2.66)	1.33 (0.45, 2.21)
≥65	ref	ref	ref
Race/ethnicity			
Non-Hispanic, white only	ref	ref	ref
Non-Hispanic, black only	0.78 (0.49, 1.06)	**0.73 (0.49, 0.97)**	0.79 (0.55, 1.03)
Hispanic	0.98 (0.62, 1.33)	0.75 (0.48, 1.02)	0.98 (0.69, 1.27)
Non-Hispanic, other or multiple races	1.00 (0.59, 1.40)	0.98 (0.52, 1.43)	0.97 (0.64, 1.30)
Educational status			
Some college education or less	1.22 (0.67, 1.77)	1.21 (0.68, 1.74)	1.02 (0.52, 1.53)
Associate/bachelor's degree	0.69 (0.36, 1.02)	**0.69 (0.46, 0.91)**	0.80 (0.56, 1.05)
Beyond college degree	ref	ref	ref
Poverty status[b]			
Below poverty	0.97 (0.72, 1.21)	**0.81 (0.62, 0.99)**	0.90 (0.68, 1.12)
Above poverty	ref	ref	ref
Occupation categories			
Physician	ref	ref	ref
Nurse practitioner/physician assistant	1.12 (0.85, 1.39)	1.19 (0.87, 1.51)	1.23 (0.93, 1.53)
Nurse	0.92 (0.67, 1.17)	1.18 (0.83, 1.54)	1.08 (0.78, 1.39)
Other clinical personnel[c]	0.81 (0.56, 1.07)	0.85 (0.63, 1.08)	0.87 (0.63, 1.11)
Non-clinical personnel[d]	**0.53 (0.24, 0.83)**	**0.61 (0.34, 0.88)**	**0.60 (0.38, 0.82)**
Occupational settings		ref	
Hospital	ref		ref

Characteristics	2012 APR[a] (95% CI)	2013 APR (95% CI)	2014 APR (95% CI)
Ambulatory care/physician's office	1.29 (0.97, 1.61)	0.95 (0.71, 1.18)	0.90 (0.64, 1.17)
Long-term care facility	0.83 (0.49, 1.16)	**0.54 (0.29, 0.79)**	**0.63 (0.35, 0.91)**
Other settings[e]	1.27 (0.73, 1.80)	0.73 (0.43, 1.03)	1.25 (0.91, 1.58)
Contact with an infant aged ≤6 months			
Yes	**1.51 (1.11, 1.92)**	1.22 (0.89, 1.55)	**1.42 (1.10, 1.74)**
No	ref	ref	ref
Employment			
Direct hire	ref	ref	ref
Licensed independent practitioner	0.75 (0.39, 1.12)	0.88 (0.54, 1.21)	0.98 (0.66, 1.31)
Contract employee	0.92 (0.57, 1.27)	1.06 (0.74, 1.38)	0.88 (0.59, 1.18)
Influenza vaccination in current season			
Yes	**1.69 (1.10, 2.28)**	1.17 (0.84, 1.51)	1.27 (0.87, 1.68)
No	ref	ref	ref
Employer policy for flu vaccination			
Yes	1.17 (0.86, 1.47)	1.22 (0.91, 1.54)	1.21 (0.94, 1.49)
No	ref	ref	ref

Note: Boldface indicates statistical significance ($p < 0.05$ comparing to reference group).

[a]Adjusted prevalence ratios, adjusted for all variables included in the table. Missing data for Tdap vaccination status for respondents who answered that they were vaccinated with tetanus vaccine since 2005 but either were not told by their doctor or were not sure which type of tetanus vaccine they received were imputed using multiple imputation under the missing-at-random assumption. Other variables with missing data, such as poverty, employment status, employer policy for influenza vaccination, age, contact with an infant ≤6 months, occupation, and occupational setting, were also imputed using this method. Estimates of Tdap vaccination were calculated with imputed data when responses to one or more questions were unknown. Imputations were done using the logistic regression Fractional Conditional Specification multiple imputation method, with age group, race/ethnicity, education, poverty, occupation, occupational setting, contact with an infant ≤6 months, employment status, influenza vaccination status, and employer policy for influenza vaccination as predictors, generating 10 imputed data sets. Tdap vaccination coverage proportion and the adjusted prevalence ratio, based on the predictive marginal under the multivariable logistic regression model, was calculated for each imputed data set and corresponding variances and covariances were calculated using two-way cross tabulations and logistic regression analysis, respectively. The results from the 10 imputed data sets were combined for overall inferences, accounting for variability between imputations.

[b]Poverty status was defined based on the reported number of people and children living in the household and annual household income, and the U.S. Census poverty thresholds (www.census.gov/data/tables/time-series/demo/income-poverty/historical-poverty-thresholds.html). As determined by the U.S. Census Bureau, for the 2014–2015 season below poverty = total family income of < $24,008 for a family of four with two minors as of 2014; for the 2013–2014 season below poverty = total annual family income of < $23,624 for a family of four with two minors as of 2013; for the 2012–2013 season below poverty = total annual family income of < $23,283 for a family of four with two minors as of 2012.

[c]Allied health professionals, technicians, and technologists.

[d]Administrative support staff members or manager and nonclinical support staff members (including food service workers, laundry workers, janitors, and members of the housekeeping and maintenance staffs).

[e]Dentist office or dental clinic, pharmacy, laboratory, public health setting, healthcare education setting, emergency medical services setting, or other setting where clinical care or related services was provided to patients.

APR, adjusted prevalence ratios; Tdap, tetanus toxoid, reduced diphtheria toxoid, and acellular pertussis vaccine.

Table 4

Sensitivity Analysis of Tdap Vaccination Coverage, Healthcare Personnel Internet Panel Survey, 2012–2014, U.S.

Sensitivity analysis	April 2012 survey		April 2013 survey		April 2014 survey	
	Sample size, *n*	% vaccinated (95% CI)	Sample size, *n*	% vaccinated (95% CI)	Sample size, *n*	% vaccinated (95% CI)
Overall Tdap vaccination	2,038	34.8 (30.6, 39.0)	1,613	40.2 (36.1, 44.4)	1,633	42.4 (38.7, 46.0)
Lower bound[a]	2,038	29.1 (25.9, 32.3)	1,613	33.6 (30.1, 37.2)	1,633	35.0 (31.7, 38.4)
Upper bound[b]	2,038	48.4 (44.7, 52.1)	1,613	51.3 (47.5, 55.2)	1,633	56.0 (52.4, 59.6)

[a]All excluded respondents (those who answered my doctor did not say or not sure to the question about the type of tetanus vaccination received) were assumed to be unvaccinated with Tdap vaccination.

[b]All excluded respondents (those who answered my doctor did not say or not sure to the question about the type of tetanus vaccination received) were assumed to be vaccinated with Tdap vaccination.

Tdap, tetanus toxoid, reduced diphtheria toxoid, and acellular pertussis vaccine.