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RESEARCH PAPER

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Disparities in uptake of 13-valent pneumococcal conjugate vaccine among older adults in the United States

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ABSTRACT

Background: In September 2014, 13-valent pneumococcal conjugate vaccine (PCV13) was universally recommended for all US adults aged ≥65 years. Adult PCV13 coverage, including whether disparities in uptake exist, however, is not well-described.

Methods: We used a monthly series of cross-sectional analyses of administrative medical and prescription claims data collected by IQVIA and linked to sociodemographic data collected by Experian to estimate overall and subpopulation-level uptake of PCV13 among US adults aged ≥65 years.

Results: Among adults aged ≥65 years, 43.3% received PCV13 by the end of November 2017. Race/ethnicity, annual household income, education status, and neighborhood urbanicity were strongly related to PCV13 uptake among adults aged ≥65 years. Lower uptake of PCV13 was observed for non-Hispanic black (36.3%) and Hispanic (30.0%) adults (*vs* 45.6% for non-Hispanic whites, $P < .01$), the poor (30.7% *vs* 54.2% among lowest *vs* highest income deciles, $P < .01$), adults with low educational status (33.0% *vs* 49.0% among those without high school education *vs* college educated, $P < .01$), and those living in rural communities (22.9%) or urban/inner-city (33.8%) areas (*vs* 45.8% in suburban areas, $P < .01$).

Conclusions: PCV13 uptake among adults aged ≥65 occurred rapidly in the three years after universal recommendation in September 2014. Yet, poor and minority communities, rural and urban/inner-city areas, and communities with low educational attainment had substantially lower PCV13 coverage. These same populations are at increased risk of pneumococcal disease. In order to maximize the benefits of pneumococcal vaccination, further targeted and tailored interventions to increase PCV13 uptake in these underserved populations are still necessary.

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Introduction

In September 2014, the US Centers for Disease Control and Prevention (CDC) Advisory Committee on Immunization Practice (ACIP) recommended 13-valent pneumococcal conjugate vaccine (PCV13) for all adults aged ≥65 years.[1] Use of PCV13 was based primarily on results of the Community-Acquired Pneumonia Immunization Trial in Adults (CAPiTA) study, which showed that PCV13 reduced vaccine-type pneumococcal community-acquired pneumonia (CAP) in older adults.[2] ACIP estimated that approximately 12,000 cases of vaccine-type CAP would be avoided with the added use of PCV13 in adults aged ≥65 years at the time of the 2014 recommendation.[1,3,4]

In the years following this updated ACIP pneumococcal vaccination recommendation, however, data describing PCV13 uptake among adults aged ≥65 years are limited. CDC does routinely assess uptake of adult pneumococcal vaccination as part of the National Health Interview Survey (NHIS) and the Behavioral Risk Factor Surveillance System (BRFSS), however, both surveys have two primary limitations. First, data are primarily self-reported in both surveys and are subject to recall bias. Secondly, and more importantly, neither BRFSS nor NHIS offer vaccine-specific estimates of uptake for adult pneumococcal vaccination now that two vaccines are recommended. That is, both surveys ask respondents "have you ever had any pneumococcal vaccine?" This prevents both surveys from distinguishing between PCV13 and 23-valent pneumococcal plain-polysaccharide vaccine (PPV23) uptake.

A CDC report of Medicare enrollees estimated that 32% of Medicare beneficiaries had received PCV13 by September 2016, and that non-Hispanic black and Hispanic adults had lower uptake of PCV13 compared to non-Hispanic white adults.[5] However, uptake of adult PCV13 has occurred rapidly, and more recent uptake estimates are not available. Moreover, the CDC report only evaluated differences in PCV13 uptake by race/ethnicity. We estimated national-level PCV13 uptake in the years following updated ACIP adult pneumococcal recommendations through November of 2017 among US adults aged ≥65 years, and determined if disparities in PCV13 uptake existed across a large number of important sociodemographic factors (ie, beyond race alone).

Results

Overall estimated PCV13 uptake

At the end of September 2014, an estimated 1.2% of adults aged ≥65 years in the United States had ever received PCV13 based on the IQVIA stable panel (after applying inverse

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proportional US population weights). By the end of September 2015, however, that number had climbed to 15.8% and was 31.5% by the end of September 2016. At the end of our study period (November 30, 2017), an estimated 43.3% (22,223,586/51,341,406) of US adults aged ≥65 years had received PCV13 (Figure 1).

Subpopulation-specific uptake of PCV13

As of November 30, 2017, an estimated 51,341,406 persons were aged ≥65 years in the United States (based on the linear interpolation method described in the Methods section). Of which, Experian sociodemographic data were available for 34,510,923 (67.2%). Subpopulation-specific estimates of PCV13 uptake in adults aged ≥65 years were based on 8,133,847 individuals (23.6% of Experian population aged ≥65 years; 15.8% of total US population aged ≥65 years) who were identified in both the IQVIA stable panel and the Experian database (ie, IQVIA-Experian-linked population). Within the IQVIA-Experian-linked population, median age was 73 years and 56.1% were female. Nearly all adults were non-Hispanic white (80.1%), non-Hispanic black (8.2%), or Hispanic (6.0%). Median annual household income was $53,000 and most respondents were retired (68.5%), lived in a suburban/metropolitan area outside of a major urban center (85.0%), and owned (*vs* rented) their primary home (89.3%). Roughly a third (32.8%) had completed a four-year college degree. A minority of adults had children (age <18 years) in the home (12.4%) (Table 1). Compared to the general US population of adults aged ≥65 years,[6-9] IQVIA-Experian-linked adults were similar in age (median for both was 73 years) but had a higher proportion of non-Hispanic whites (80.1% *vs* 77.3%), a higher proportion that completed high school (90.2% *vs* 84.3%), a higher median income ($53,000 *vs* $42,113), and higher percentage of home ownership (89.3% *vs* 78.7%).

The estimated uptake of PCV13 by the end of November 2017 was the same for adults aged ≥65 years in the IQVIA-Experian-linked database as it was for all patients originally identified in IQVIA (ie, 43.3% for both). At the crude level (Table 1), race/ethnicity, annual household income, education status, and neighborhood urbanicity were strongly related to PCV13 uptake (Figure 2). Lower uptake of PCV13 was observed for non-Hispanic black (36.3%) and Hispanic (30.0%) adults (*vs* 45.6% for non-Hispanic whites, $P < .01$), adults with low socio-economic (30.7% *vs* 54.2% among lowest *vs* highest income deciles, $P < .01$) or educational status (33.0% *vs* 49.0% among those without high school education *vs* college educated, $P < .01$), and those living in rural communities (22.9%) or urban/inner-city (33.8%) areas (*vs* 45.8% in suburban areas, $P < .01$) (Table 1, Figure 2).

Fully-adjusted log binomial regression analyses were essentially identical to crude results, and revealed that race/ethnicity, annual household income, education status, and urbanicity were all still related to PCV13 uptake, even after simultaneous adjustment (Table 2). Sensitivity analyses showed that log binomial regression results were similar regardless of whether respondents who answered "don't know/not sure" were included in the analysis or not (data not shown).

Discussion

Our study provides contemporary estimates of PCV13 uptake among adults aged ≥65 years following recommendation by ACIP in September 2014 for universal use in this age group.[1] Results showed that PCV13 uptake among adults aged ≥65 years occurred rapidly in the years following ACIP recommendation in late 2014, reaching an estimated 43% by the end of November 2017. PCV13 uptake, however, is still below historical self-reported PPV23 uptake levels (60–70%) in adults aged ≥65 years and well-short of the Healthy People 2020 goal of 90% pneumococcal vaccination coverage in this age group.[4,10]

A closer look at PCV13 uptake revealed that poor and minority adults, adults living in rural and urban/inner-city areas, and adults with low educational attainment were much

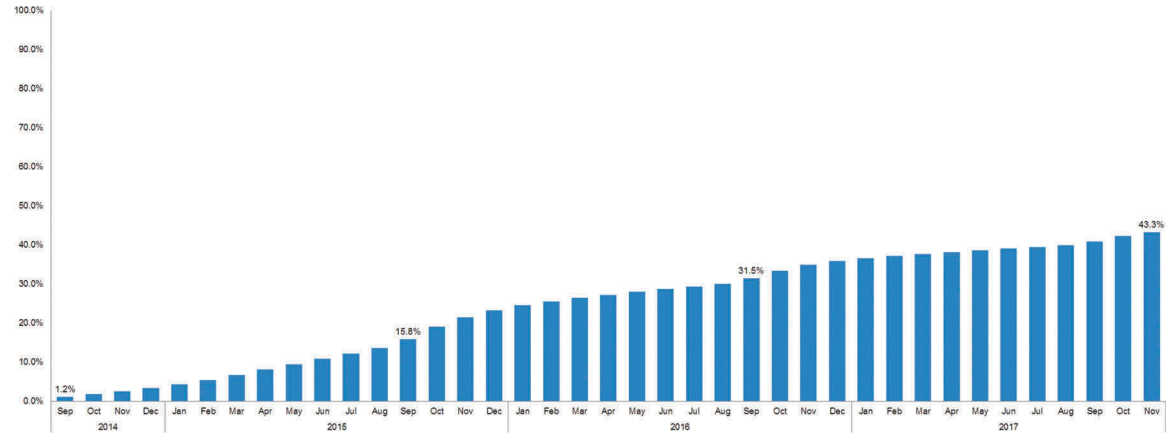

Figure 1. Percentage of US Adults Aged ≥65 Years Who Received PCV13 by month in the IQVIA Database, September 2014 – November 2017. [a,b]

PCV13 = 13-valent pneumococcal vaccine.

[a] PCV13 was recommended for universal use for all adults aged ≥65 years in September of 2014.

[b] Based on monthly IQVIA "stable panel" claims for PCV13 receipt extrapolated to the US population using inverse proportional weighting to account for the fact that the stable panel is not a perfect capture of all US medical and prescription services. Weights for each site of care (ie, outpatient practice, pharmacy, or the hospital setting) are determined by comparing the proportion of providers captured in the stable panel to national estimates of the total number of US providers in each setting.

Table 1. Proportion of US Adults Aged ≥65 Years Who Ever Received PCV13 by Sociodemographic Characteristic in the IQVIA-Experian-Linked Database, November 2017 (n = 8,133,847).

Sociodemographic Characteristic	IQVIA-Experian-Linked Population *n (%)*	Ever Received PCV13 [a] %
Total	8,133,847 (100.0)	43.3
Age		
65–74	4,613,394 (56.7)	48.3
75–84	2,559,331 (31.5)	43.2
≥85	961,122 (11.8)	25.7
Gender		
Female	4,565,850 (56.1)	45.1
Male	3,566,645 (43.8)	41.5
Race/Ethnicity		
White, non-Hispanic	6,561,338 (80.1)	45.6
Black, non-Hispanic	667,364 (8.2)	36.3
Hispanic	490,523 (6.0)	30.0
Asian or Other, non-Hispanic	229,524 (2.8)	36.4
Unknown	185,098 (2.3)	44.2
Annual Household Income Adjusted for State of Residence		
Highest Decile (10%)	999,791 (12.3)	54.2
90th percentile	950,424 (11.7)	51.3
80th percentile	922,036 (11.3)	49.1
70th percentile	909,280 (11.2)	47.2
60th percentile	875,175 (10.8)	43.9
50th percentile	845,927 (10.4)	41.2
40th percentile	802,224 (9.9)	38.9
30th percentile	739,335 (9.1)	36.7
20th percentile	624,656 (7.7)	33.8
Lowest Decile (10%)	461,657 (5.7)	30.7
Unknown	3,342 (0.0)	43.0
Homeowner Status		
Home owner	7,265,823 (89.3)	44.7
Renter	572,377 (7.0)	32.7
Unknown	295,647 (3.6)	37.4
Education Status		
Graduate degree (master's, doctoral, professional)	1,023,426 (12.6)	49.5
College degree	1,641,227 (20.2)	48.6
Some college, no degree	1,479,763 (18.2)	43.2
High school diploma or equivalent	3,189,437 (39.2)	42.3
Less than High School	791,131 (9.7)	33.0
Unknown	8,863 (0.1)	42.9
Occupational Status		
Retired	5,571,917 (68.5)	42.5
Employed – blue collar, farming, fishing, or forestry	373,891 (4.6)	40.1
Employed – office work or sales	471,321 (5.8)	44.7
Employed – other	1,707,855 (21.0)	46.8
Unknown	8,863 (0.1)	42.9
Urbanicity		
Suburban/Metropolitan	6,914,586 (85.0)	45.8
Urban	1,113,843 (13.7)	33.8
Rural	105,041 (1.3)	22.9
Unknown	377 (0.0)	50.2
Geographic Region [b]		
New England	428,700 (5.3)	53.5
Mideast	1,365,370 (16.8)	48.3
Great Lakes	1,307,445 (16.1)	45.1
Plains	473,188 (5.8)	34.1
Southeast	2,409,353 (29.6)	50.7
Southwest	842,980 (10.4)	31.5
Rocky Mountain	247,485 (3.0)	40.5
Far West	1,059,326 (13.0)	32.1
Children Living in Household		
Yes	1,008,230 (12.4)	41.4
No	7,125,617 (87.6)	43.7
Influenza Vaccination Status		
Not Vaccinated in Last Year or Unknown	1,995,496 (24.5)	24.8
Vaccinated in Last Year	6,138,351 (75.5)	68.8

PCV13 = 13-valent pneumococcal vaccine.

[a] Based on November 30, 2017 IQVIA "stable panel" claims for PCV13 receipt extrapolated to the US population using inverse proportional weighting to account for the fact that the stable panel is not a perfect capture of all US medical and prescription services. Weights for each site of care (ie, outpatient practice, pharmacy, or the hospital setting) are determined by comparing the proportion of providers captured in the stable panel to national estimates of the total number of US providers in each setting.

[b] Regional classifications were based on Bureau of Economic Analysis designations: http://www.bea.gov/regional/docs/regions.cfm.

New England = Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont. *Mideast* = Delaware, District of Columbia, Maryland, New Jersey, New York, and Pennsylvania. *Great Lakes* = Illinois, Indiana, Michigan, Ohio, and Wisconsin. *Plains* = Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota. *Southeast* = Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia. *Southwest* = Arizona, New Mexico, Oklahoma, and Texas. *Rocky Mountain* = Colorado, Idaho, Montana, Utah, and Wyoming. *Far West* = Alaska, California, Hawaii, Nevada, Oregon, and Washington.

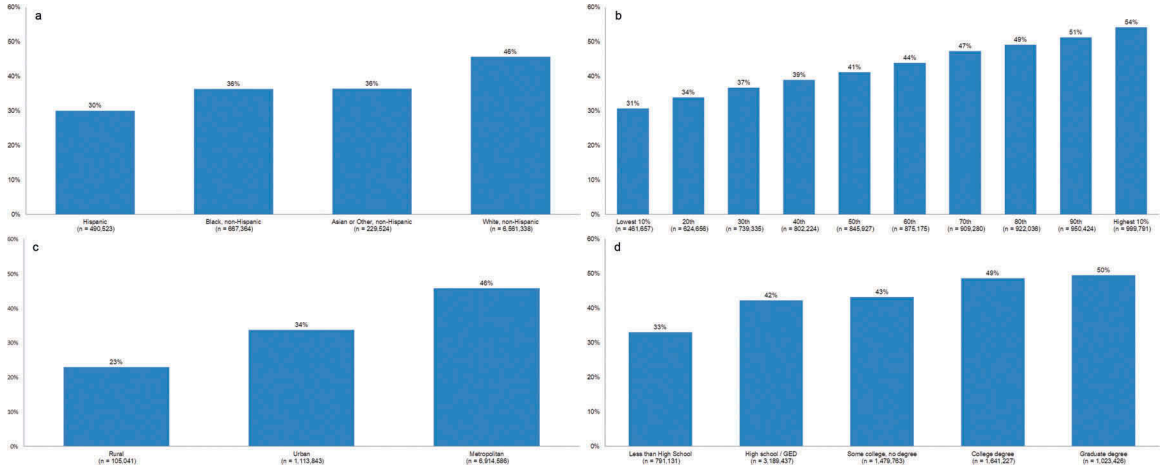

Figure 2. Percentage of US Adults Aged ≥65 Years Who Received PCV13 by (a) Race/Ethnicity, (b) Annual Household Income Decile, (c) Neighborhood Urbanicity, and (d) Education Level in the IQVIA-Experian-Linked Database, November 30, 2017 (n = 8,133,847). [a]

PCV13 = 13-valent pneumococcal vaccine.

[a] Based on November 30, 2017 IQVIA "stable panel" claims for PCV13 receipt extrapolated to the US population using inverse proportional weighting to account for the fact that the stable panel is not a perfect capture of all US medical and prescription services. Weights for each site of care (ie, outpatient practice, pharmacy, or the hospital setting) are determined by comparing the proportion of providers captured in the stable panel to national estimates of the total number of US providers in each setting.

less likely to receive PCV13 following ACIP recommendation. This is concerning given that these communities have previously been identified to be at increased risk for pneumococcal disease.[11-15] Further, disparities in adult PCV13 uptake could be especially problematic given that lower childhood PCV13 coverage rates have long been observed in the same communities.[14,16,17] These multiplicative, detrimental effects could allow pneumococcal reservoirs to remain in many underserved communities[18] – a concept that should be more thoroughly investigated.

Our findings also have important vaccine policy implications. When making the 2014 recommendation for all adults aged ≥65 years to receive PCV13, ACIP decided the recommendation would be contingent on a future re-evaluation of the benefit of continued adult PCV13 use in the context of a long-standing pediatric PCV13 immunization program.[1] Yet, a decision to remove the current recommendation for adult PCV13 use could cement the disparities in access to PCV13 among older adults observed in our study, leaving these already underserved populations even more vulnerable to disease.

Like previous studies reporting racial/ethnic disparities in adult immunization uptake,[19-26] results from our study demonstrated that, compared to non-Hispanic whites aged ≥65 years, of whom 46% had received PCV13, only 36% and 30% of non-Hispanic black and Hispanics adults of the same age, respectively, had received PCV13 three years after the September 2014 age-based ACIP recommendation (November 30, 2017). Racial/ethnic disparities persisted even after statistical adjustment for education, income, occupation, and place of residence, suggesting that these racial/ethnic disparities in PCV13 uptake cannot be solely attributed to differences in sociodemographic factors. This is especially troubling given that rates of pneumococcal disease are significantly higher for racial minorities.[11,12,14] Racial/ethnic differences in pneumococcal vaccination rates that were not accounted for by demographic or socioeconomic factors are likely multifactorial and could include differences in cultural beliefs or attitudes toward vaccination and preventive care,[27-29] and institutional bias in the healthcare system.[30] Use of targeted and tailored interventions with culturally-appropriate messaging have been shown to improve adult vaccination rates in minority populations[31,32] and should be implemented more broadly to reduce racial/ethnic disparities in PCV13 uptake.

In addition to race/ethnicity, socioeconomic status was strongly related to PCV13 uptake, with a clear linear relationship between higher PCV13 uptake and increasing decile of annual household income. Differences in PCV13 uptake among adults aged ≥65 years between the poorest and richest income deciles were especially striking (31% *vs* 54%). Like racial differences, socioeconomic differences in PCV13 uptake persisted even after multivariable adjustment for other factors. These differences also remained despite the fact that all adults aged ≥65 years in the United States have access to PCV13 with zero dollar out-of-pocket costs provided by Medicare Part B. Like racial/ethnic minorities, risk of pneumococcal disease is also higher among persons with low socioeconomic status.[13-15] Previous work has described the relationship between location-based socioeconomic measures and health outcomes across a variety of communicable and noncommunicable diseases.[33] This relationship is complex, and likely reflects an amalgam of individual and societal risk factors, such as the lack of access to reliable transportation,[34] inability to take time-off from work,[35] and fewer primary-care physicians serving the community.[36] To improve adult vaccination coverage in low-income communities, interventions such as in-home well-care visits,[37,38] mobile vaccination clinics,[39] and monetary incentives,[40,41] have been found to improve influenza vaccination rates and could be considered for pneumococcal vaccination.

Compared to older adults living in suburban/metropolitan neighborhoods, those living in rural areas or urban/inner-city areas were also significantly less likely to receive

Table 2. Relative Risks (RR) and 95% Confidence Intervals (95%CI) of Ever Receiving PCV13 Among US Adults Aged ≥65 Years by Sociodemographic Characteristic in the IQVIA-Experian-Linked Database, November 2017 (n = 8,133,847).

Sociodemographic Characteristic	Crude RR	95%CI	Fully Adj. RR	95%CI
Age				
65–74	1.00		1.00	
75–84	0.89	(0.89, 0.89)	0.88	(0.88, 0.88)
≥85	0.53	(0.53, 0.53)	0.52	(0.52, 0.53)
Gender				
Male	1.00		1.00	
Female	0.92	(0.92, 0.92)	0.92	(0.92, 0.92)
Race/Ethnicity				
White, non-Hispanic	1.00		1.00	
Black, non-Hispanic	0.79	(0.79, 0.79)	0.80	(0.80, 0.80)
Hispanic	0.65	(0.65, 0.65)	0.71	(0.71, 0.72)
Asian or Other, non-Hispanic	0.79	(0.79, 0.80)	0.86	(0.85, 0.86)
Unknown	0.96	(0.96, 0.97)	0.97	(0.96, 0.97)
Annual Household Income Adjusted for State of Residence				
Highest Decile (10%)	1.00		1.00	
90th percentile	0.94	(0.94, 0.94)	0.94	(0.94, 0.95)
80th percentile	0.90	(0.90, 0.90)	0.90	(0.90, 0.91)
70th percentile	0.87	(0.87, 0.87)	0.87	(0.87, 0.87)
60th percentile	0.80	(0.80, 0.80)	0.81	(0.81, 0.81)
50th percentile	0.75	(0.75, 0.76)	0.76	(0.76, 0.76)
40th percentile	0.71	(0.71, 0.71)	0.72	(0.72, 0.72)
30th percentile	0.67	(0.67, 0.67)	0.68	(0.68, 0.68)
20th percentile	0.62	(0.62, 0.62)	0.63	(0.63, 0.64)
Lowest Decile (10%)	0.56	(0.56, 0.56)	0.59	(0.59, 0.59)
Unknown	0.79	(0.77, 0.80)	0.67	(0.66, 0.79)
Homeowner Status				
Homeowner	1.00		1.00	
Renter	0.73	(0.72, 0.73)	0.77	(0.76, 0.77)
Unknown	0.83	(0.83, 0.83)	0.84	(0.84, 0.84)
Education Status				
Graduate degree (master's, doctoral, or professional)	1.00		1.00	
College degree	0.98	(0.98, 0.98)	0.98	(0.98, 0.98)
Some college, no degree	0.87	(0.87, 0.87)	0.88	(0.88, 0.88)
High school diploma or equivalent	0.85	(0.85, 0.85)	0.84	(0.84, 0.84)
Less than High School	0.66	(0.66, 0.66)	0.68	(0.68, 0.69)
Unknown	0.86	(0.85, 0.87)	0.84	(0.83, 0.85)
Occupational Status				
Retired	1.00		1.00	
Employed: blue collar, farming, fishing, or forestry	0.94	(0.94, 0.94)	0.95	(0.94, 0.95)
Employed: office work or sales	1.05	(1.04, 1.05)	1.05	(1.04, 1.05)
Employed: other	1.10	(1.09, 1.10)	1.09	(1.09, 1.09)
Unknown	1.00	(0.99, 1.01)	0.99	(0.98, 1.01)
Urbanicity				
Suburban/Metropolitan	1.00		1.00	
Urban	0.73	(0.73, 0.73)	0.70	(0.70, 0.70)
Rural	0.50	(0.49, 0.50)	0.49	(0.49, 0.49)
Unknown	1.09	(1.04, 1.15)	1.07	(1.02, 1.18)
Geographic Region [a]				
New England	1.00		1.00	
Mideast	0.90	(0.90, 0.90)	0.90	(0.90, 0.90)
Great Lakes	0.84	(0.84, 0.84)	0.84	(0.84, 0.84)
Plains	0.63	(0.63, 0.63)	0.64	(0.64, 0.64)
Southeast	0.94	(0.94, 0.94)	0.94	(0.94, 0.94)
Southwest	0.58	(0.58, 0.58)	0.59	(0.59, 0.59)
Rocky Mountain	0.75	(0.75, 0.75)	0.75	(0.74, 0.75)
Far West	0.60	(0.60, 0.60)	0.64	(0.64, 0.65)
Children (<18 years) Living in Household				
No	1.00		1.00	
Yes	0.94	(0.94, 0.94)	0.96	(0.96, 0.96)
Influenza Vaccination Status				
Vaccinated in Last Year	1.00		1.00	
Not Vaccinated in Last Year or Unknown	0.36	(0.36, 0.36)	0.18	(0.18, 0.18)

PCV13 = 13-valent pneumococcal vaccine.

[a] Regional classifications were based on Bureau of Economic Analysis designations: http://www.bea.gov/regional/docs/regions.cfm.

New England = Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont. *Mideast* = Delaware, District of Columbia, Maryland, New Jersey, New York, and Pennsylvania. *Great Lakes* = Illinois, Indiana, Michigan, Ohio, and Wisconsin. *Plains* = Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota. *Southeast* = Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia. *Southwest* = Arizona, New Mexico, Oklahoma, and Texas. *Rocky Mountain* = Colorado, Idaho, Montana, Utah, and Wyoming. *Far West* = Alaska, California, Hawaii, Nevada, Oregon, and Washington.

PCV13. Previous research has shown that vaccination coverage can be lower in these areas where there may be a larger reliance on nontraditional locations (eg, pharmacies, retail stores, workplaces, churches) to receive vaccination.[42-45] Rural residents, who were especially under-immunized with PCV13 in our study, can face unique barriers to vaccination including poverty, longer travel distance, and limited traditional settings to receive routine preventative care.[46]

These lower vaccination rates are compounded by recent CDC data showing that rural residents have higher rates of mortality related to chronic lower respiratory disease.[47] Broader use of community-based mass-immunization clinics held at non-traditional settings including the workplace, churches, retail stores, or pharmacies could help improve immunization coverage in communities with limited traditional options for adult vaccination.[48]

Finally, results from our study also suggest that education level may play an important role as well. After controlling for demographic and socioeconomic factors, compared to those that graduated college, older adults who never finished high school were 31% less likely to be vaccinated with PCV13 in our study. Previous research has demonstrated that a simple, low-literacy educational tool increased pneumococcal vaccination rates among elderly populations with low levels of literacy and education,[49] and similar approaches could be applied to pneumococcal vaccination efforts.

As demonstrated with the Vaccines for Children (VFC) program, broad systematic support of pediatric immunization has dramatically reduced disparities among children across all recommended vaccines.[50] Adult immunization programs, however, have been slow to evolve for multiple reasons, many of which extend beyond vaccine-specific challenges. These include variable insurance coverage among patients, a lack of incentives for healthcare providers to deliver preventive care, and a lack of a 'medical home' for adult patients.[51] These factors are often heightened in under-served communities where general healthcare access issues are more acute. Thus, in addition to vaccine-specific interventions discussed previously, broader preventive-care efforts for adults in vulnerable communities are needed.

Our study is not without limitations. IQVIA data, although used routinely for evaluations of medical and prescription utilization,[52] do not perfectly capture PCV13 utilization. To address this issue, our analysis was limited to a stable panel of providers where IQVIA has a robust capture of procedural, diagnosis, and prescription claims. These estimates were then extrapolated, using inverse proportional weighting, to the entire US population. In doing this, it is assumed that the stable panel is generally representative of other practices, pharmacies, and hospitals for which IQVIA did not have reliable data. If this assumption was not true, however, generalizability to all US areas may not be appropriate. Additionally, if older adults who tended to be underimmunized were differentially underrepresented in the IQVIA data capture, it is possible disparities observed in our study could be underestimated. It was reassuring, however, that our estimate of US PCV13 uptake in older adults in September 2016 was identical to the CDC estimate of uptake in the Medicare population at the same time point (both 32% in September 2016).[5]

Another important limitation is that patient-level sociodemographic information was only available for older adults who matched in the Experian dataset. Experian data come primarily from consumer participation in the credit market, and 67% of all US adults aged ≥65 years matched in Experian. It is possible, however, that poor, minority, rural, or poorly-educated elderly populations are less likely to qualify for, or participate in, the credit market, leading to differential exclusion of these populations during the Experian matching process. This too would mean that the disparities we uncovered in adult PCV13 uptake could be even more severe if sociodemographic information would have been available for patients who didn't match in Experian. However, estimated PCV13 uptake for the overall IQVIA stable-panel population and the subpopulation of IQVIA patients that matched in Experian was similar (both 43% as of November 2017). This suggests that bias stemming from the Experian-matching process likely had minimal impact on our subpopulation-specific estimates of PCV13 uptake.

In addition, for subpopulation-specific uptake estimates, it was also assumed that the IQVIA-Experian-linked population (after applying IQVIA inverse proportional weights) has a sociodemographic makeup that is representative of the United States. It was reassuring that the magnitude of differences in PCV13 uptake in our study by race/ethnicity were comparable to that of a previous study of racial differences in PCV13 uptake among US Medicare beneficiaries.[5] This further suggests that the IQVIA-Experian-linked population is probably generally representative of the US population. However, future studies in other populations should confirm our findings.

Despite limitations, our study comprehensively evaluated the uptake of PCV13 following ACIP recommendations in September 2014. Given the novel approach used in our study, future research should examine uptake of other adult vaccines (eg, influenza and herpes zoster) using a similar design. In the near future, ACIP will formally revisit the current adult pneumococcal vaccination recommendations, with a specific focus on determining whether there is continued utility for PCV13 use in adults.[53] In addition to emerging data that reaffirmed the effectiveness of PCV13 in a broad population of older US adults,[54,55] results from our study may help inform this important decision. Namely, although PCV13 uptake did occur rapidly in the three years following ACIP recommendation, that uptake may be beginning to stall. Based on results from our study, the recent leveling-off of PCV13 uptake is likely rooted in the fact that it is taking longer for updated pneumococcal guidelines to find their way into poor, minority, and geographically-remote communities. Removing the recommendation for adult use of PCV13 would essentially cement these current disparities in PCV13 utilization in the very communities at increased risk for pneumococcal disease.[11-14,18] Instead, in the years between now and the availability of expanded-valency PCVs, which are on the horizon, targeting traditionally underserved communities (eg, poor, minority, rural) with evidence-based interventions and proven health system-wide changes (eg, adoption of immunization information systems, implementation of standing orders for vaccination, assigning non-physician personnel vaccination responsibilities, continuously monitoring vaccination rates, and ensuring in-person clinician recommendation)[25,28,51] would be prudent.

Methods

Outcome

Our study had two primary outcomes of interest: (i) to determine what proportion of US adults aged ≥65 years received PCV13 following the 2014 age-based recommendation by ACIP[1] (September 2014 – November 2017), and (ii) to

determine whether certain sociodemographic characteristics were related to uptake of the vaccine. The study populations used to evaluate these outcomes are described separately below.

Measuring overall PCV13 uptake

We obtained data about PCV13 utilization in adults aged ≥65 years from IQVIA's (Durham, NC, formerly IMS Health and QuintilesIMS) anonymized claims data. Databases for three settings of care were used: office-based medical claims (Dx), pharmacy-based claims (LRx), and hospital-based charge data master (CDM) claims. We defined an individual as vaccinated if she or he had any medical or prescription claim for PCV13 from one of these three databases.

IQVIA's Dx data are comprised of >1 billion electronic medical claims, annually, from office-based medical practices, ambulatory clinics, and general healthcare sites, and include patient-level procedure and diagnosis information. The LRx database contains pharmacy-based, adjudicated claims stemming from a variety of payer types including commercial insurance plans, Medicaid, Medicare Part D, and cash-only transactions. These data are nationally representative and capture more than 92% of all US retail pharmacy-based claims (nearly 4 billion claims annually). Finally, IQVIA receives roughly 330 million US hospital-based claims per year as part of its hospital CDM database. The CDM contains patient-level data from participating hospitals, groups of hospitals, or hospital units. These Dx, LRx, and CDM data are anonymous at the patient level.

IQVIA's Dx, LRx, and CDM databases, however, are not a complete capture of all US medical and prescription claims. To account for this, IQVIA has a proprietary algorithm for determining which outpatient practices, pharmacies, and hospitals are well-captured over time in the Dx, LRx, and CDM databases, respectively.[56] These well-captured sites are referred to as the IQVIA "stable panel" and are defined on a monthly basis. Estimates derived from this stable panel are extrapolated to the entire US population using inverse proportional weighting to account for the fact that the stable panel is not a perfect capture of all US medical and prescription services. Weights for each setting of care (ie, outpatient practice, pharmacy, or the hospital setting) are determined by comparing the proportion of providers captured in the stable panel to national estimates of the total number of US providers in each setting.[56,57] Estimates for the total number of all US providers in the outpatient, pharmacy, and hospital setting were obtained from the American Medical Association (AMA), the National Council for Prescription Drug Programs (NCPDP), and the American Hospital Association (AHA), respectively.

All PCV13 administrations for patients aged ≥65 years identified in the Dx, LRx, or CDM databases were summed together and then extrapolated to the entire US population using the inverse-proportional weighting method[56,57] described previously to estimate the total number of doses of PCV13 administered each month in the United States. This served as the numerator for US PCV13 uptake estimates. We repeated this process each month from September 2014 through November 2017.

The denominator for calculating monthly PCV13 coverage percentages was based on US Census estimates for the total US population aged ≥65 years in the same year. We calculated monthly estimates of population size using linear interpolation of consecutive annual US Census population size estimates.

Measuring subpopulation-specific PCV13 uptake

Only a limited set of patient-level attributes were available in IQVIA claims data (eg, age and gender). In order to examine variations in PCV13 uptake across various sociodemographic characteristics (eg, race/ethnicity, socioeconomic status, occupation, education, and geographic location), IQVIA linked the PCV13 uptake data from the November 2017 cross-sectional IQVIA stable panel (the most recent time period in our study) to Experian Marketing Services ConsumerView™ data (Experian Information Solutions, Inc., Costa Mesa, CA). Experian sociodemographic data elements are derived from a national database that contain information about individual-level demographic, lifestyle, and financial attributes for roughly 300 million persons and 126 million households across the United States. Data are collected from hundreds of public and proprietary sources, including self-reported information, public records, and purchase-transaction information.

To calculate subpopulation-specific estimates of PCV13 uptake, the analysis was limited to the subpopulation of IQVIA patients that matched in the Experian database (ie, IQVIA-Experian-linked database). These subpopulation-specific uptake estimates were adjusted using the same IQVIA inverse proportional weighting methodology that was used when measuring overall PCV13 uptake (described previously).

Privacy protection

All data remained de-identified throughout the entire data collection, linkage, and analysis process.[58] All personal health information (PHI) were removed or encrypted by a proprietary, automated de-identification engine (ie, prior to being collected by IQVIA). This process has been certified as Health Insurance Portability and Accountability Act (HIPAA) compliant and institutional review board-exempt. This same de-identification engine was used at Experian prior to linking sociodemographic data with IQVIA claims data. Thus, at no point were any of the study investigators, IQVIA, or Experian able to access any PHI data.

Exposure and participant characteristics

We compared PCV13 uptake across the following characteristics: age, sex, race/ethnicity, decile of annual household income adjusted for US state of residence, educational and occupational status, geographic region, neighborhood urbanicity, number of children living in the household, and influenza vaccination receipt in the prior 12 months.

Statistical analysis

We reported univariate relationships between PCV13 use and baseline characteristics. Crude and multivariable-adjusted log binomial regression analyses were used to identify factors associated with PCV13 uptake among adults aged ≥65 years (ever *vs* never) and were presented as relative risks (RR) and 95% confidence intervals (95%CI). For log binomial regression, we used likelihood ratio Chi-square tests to determine improved statistical fit. We incorporated IQVIA inverse proportional US population weights[56] into all analyses. Finally, we performed sensitivity analyses to determine if results were similar regardless of whether missing sociodemographic data were excluded from the analysis or modeled as a separate 'unknown' category. Statistical analyses were conducted using SAS version 9.4 (SAS Institute Inc., Cary, NC).

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Disclosure of potential conflicts of interest

JMM, FK, AC, VS, DLS, REI, LJ are all employees of Pfizer, Inc.

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