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Factors associated with receipt of mRNA-1273 vaccine at a United States national retail pharmacy during the COVID-19 pandemic

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ABSTRACT

Introduction: The emergence of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) prompted accelerated vaccine development of novel messenger RNA (mRNA)-based vaccines by Moderna and Pfizer, which received FDA Emergency Use Authorization in December 2020. The purpose of this study was to examine trends in primary series administration and multi-dose completion rates with Moderna's mRNA-1273 vaccine administered at a United States retail pharmacy.

Methods: Walgreens pharmacy data were joined to publicly available data sets to examine trends in mRNA-1273 primary series and multi-dose completion across patient race/ethnicity, age, gender, distance to first vaccination, and community characteristics. Eligible patients received their first dose of mRNA-1273 administered by Walgreens between December 18, 2020 and February 28, 2022. Variables significantly associated with on-time second dose (all patients) and third dose (immunocompromised patients) in univariate analyses were included in linear regression models. A subset of patients in selected states were studied to identify differences in early and late vaccine adoption.

Results: Patients (N = 4,870,915) who received $\geq$ 1 dose of mRNA-1273 were 57.0% White, 52.6% female, and averaged 49.4 years old. Approximately 85% of patients received a second dose during the study period. Factors associated with on-time second dose administration included older age, race/ethnicity, traveling $\leq$ 10 miles for the first dose, higher community-level health insurance, and residing in areas with low social vulnerability. Only 51.0% of immunocompromised patients received the third dose as recommended. Factors associated with third dose administration included older age, race/ethnicity, and small-town residence. Early adopters accounted for 60.6% of patients. Factors associated with early adoption included older age, race/ethnicity, and metropolitan residence.

Conclusion: Over 80% of patients received their on-time second dose of mRNA-1273 vaccine per CDC recommendations. Patient demographics and community characteristics were associated with vaccine receipt and series completion. Novel approaches to facilitate series completion during a pandemic should be further studied.

1. Background

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pandemic emerged in late 2019, prompting an international effort to accelerate the development of safe and effective vaccines to protect against the virus. Novel messenger RNA (mRNA)-based vaccines to prevent coronavirus disease 2019

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(COVID-19) were developed by Moderna (mRNA-1273; SPIKEVAX; Moderna, Inc., Cambridge, MA) and Pfizer-BioNTech (BNT162b2; COMIRNATY; Biontech, Mainz, Germany, and Pfizer, Inc., New York, NY). In December 2020, both vaccines were authorized in the United States by the Food and Drug Administration (FDA) under Emergency Use Authorization (EUA) [1–2]. Efforts at rapid vaccine distribution ensued, largely relying on community-based pharmacies to administer COVID-19 vaccines to as many Americans as quickly as possible to prevent further morbidity and mortality [3].

Led by the US Centers for Disease Control and Prevention (CDC), the Federal Retail Pharmacy Program (FRRP) was instituted to lead rapid vaccine deployment in partnership with 21 retail pharmacy partners alongside state, local, and territorial public health agencies. Walgreens, one of the largest FRRP partners, operates 8,965 retail pharmacy locations in the US, with approximately 78% of Americans living within 5 miles of a Walgreens pharmacy [4]. Walgreens also extended their services to administer vaccinations at community mass vaccination events and long-term care facilities. The accessibility of pharmacies is a critical component of the mass vaccination effort to ensure that all communities, especially those faced with health inequities, have access to COVID-19 vaccines.

Pharmacists, and more recently trained pharmacy technicians, have demonstrated ability to safely administer immunizations and have become increasingly vital partners in mass vaccine distribution over time [5]. For instance, during the 2009 H1N1 influenza pandemic, approximately 10% of adult H1N1 vaccine recipients received the vaccine from a pharmacist, with 34.2% of Americans receiving the vaccine overall [6]. The proportion of COVID-19 vaccinations administered by pharmacies is exponentially higher, with over 65,000,000 doses administered by Walgreens pharmacists or pharmacy technicians as of Spring 2022, thus demonstrating the crucial role of pharmacies in maintaining the public's health in the event of a pandemic [7].

As of February 8, 2023, the CDC reported that 92% of the US adult population $\geq$ 18 years old had received at least one dose of COVID-19 vaccine and 79% were fully vaccinated with a primary series, defined as receiving two doses of an mRNA vaccine on different days or one dose of the single-dose adenovirus vector vaccine manufactured by Janssen Biotech [8]. Contraindications to COVID-19 vaccines include a history of severe allergic reaction to a previous dose or a vaccine component [9]; yet these contraindications alone do not account for the 8% of adults who have not received even one dose of vaccine. There are many factors that impact the decision not to get immunized, with one recent systematic review estimating the COVID-19 vaccine acceptance rate in the US to be 71.4%, although acceptance rates differed greatly across subpopulations [10]. Factors that influenced COVID-19 vaccine uptake include misinformation, the polarized political environment, hesitancy toward mRNA vaccines, and mistrust of vaccination [11].

A second challenge to the COVID-19 vaccination rollout was the need to ensure that both primary series doses of the mRNA vaccines were received within the recommended timeframe. Multi-dose vaccine completion has traditionally been a challenge for providers. A large, multisite, retrospective study utilizing the Vaccine Safety Datalink cohort demonstrated on-time series completion for hepatitis A vaccines in adults to be between 25.0% and 43.6% whereas series completion for hepatitis B vaccines in adults was between 41.4% and 62.6% [12]. More recently, a retrospective study utilizing open-source longitudinal claims data reported that recombinant herpes zoster vaccine (RZV), which is recommended for adults aged 50 years and older, has a second dose completion rate of 70.4% within 6 months of the initial dose [13]. While RZV series completion rates are much higher than those reported for hepatitis A and B, there is still room for improvement. In March 2021, shortly after the mRNA COVID-19 vaccines were widely distributed, the CDC reported second dose completion rates of 88% with another 8.6% of individuals who stated their intention to receive the second dose but were not yet due for it [14]. More recent data are needed to fully understand factors associated with second dose completion rates among a large representative cohort of COVID-19 vaccine recipients.

The purpose of this study was to increase understanding of COVID-19 vaccine uptake when administered by community pharmacies by examining trends of mRNA-1273 primary series administration, including patient characteristics and regional distribution. The study also examined rates of primary dose completion among this large, representative community cohort.

2. Methods

2.1. Data inputs and sources

2.1.1. Pharmacy data

Adult patients (aged $\geq$ 18 years) who received a first dose of mRNA-1273 were identified from the Walgreens electronic data warehouse. Patients were considered eligible for inclusion in the study if their first dose of mRNA-1273 was provided by a Walgreens pharmacy between December 18, 2020 and February 28, 2022. Further, patients were considered eligible for a third primary series dose of mRNA-1273 if they received two doses of the vaccine at Walgreens and were immunocompromised based on pharmacy claims data as determined by a pharmacist.

At the time of initial vaccination, the pharmacist or technician collected demographic information from the patient including their date of birth, sex, race, and ethnicity. Location of this vaccination was also collected. Age was calculated from date of birth and categorized into the following 5 age groups: 18–21 years, 22–34, 35–54, 55–64, and $\geq$ 65. Race and ethnicity were combined into one category based on the current CDC recommended methodology [15] and organized into the following categories: Hispanic/Latino, White (not Hispanic/Latino), Black or African American, Asian, American Indian or Alaskan Native, Native Hawaiian or Other Pacific Islander, Other, and Unknown. Distance traveled by the patient for the first vaccination visit was calculated using the centroids of the patient's zip code on file and the zip code of the store where the initial vaccination was received. Distance was categorized as follows: <10, 10–49, 50–99, 100–149, 150–199, 200–249, and 250 + miles. It is important to note that patients may have travelled from home for reasons other than vaccination or moved recently without yet having their zip code on file updated; therefore, long distances may be less accurate.

2.1.2. Census data

Data from the most recent American Community Survey (ACS) 2015 – 2020 were used to identify community-level characteristics [16]. Variables considered for the study included median income, race/ethnicity, age, health insurance coverage, and education level of the community (Appendix A). ZIP Code Tabulation Areas (ZCTA) were identified at the patient-level using a crosswalk provided by the Uniform Data System [17] in order to accurately match patients to community-level characteristics.

2.1.3. Social vulnerability index

Social vulnerability was defined as the potential negative effects on communities caused by external stresses on human health. The Social Vulnerability Index (SVI) [18] was intended for disaster preparedness and emergency management; however, it is also useful for identifying communities at risk for poor medical outcomes. The overall SVI was used, rolling up census tracts to zip codes, and categorized as follows: low vulnerability (0-0.25), med-low (0.25-0.5),

med-high (0.5-0.75), and high (0.75+). Zip codes without a known SVI were classified as "Unknown", including all zip codes in Puerto Rico, which do not have an SVI classification.

2.1.4. Rural-urban commuting area codes

The US Department of Agriculture provides a classification of zip codes into one of eleven Rural-Urban Commuting Area (RUCA) codes (Appendix B) [19]. These were condensed into four categories for the current study: Metropolitan, Micropolitan, Small Town, and Rural. Some zip codes were classified as not coded and therefore did not have a RUCA assigned, in which case these patients were excluded from the analysis.

2.2. Outcomes

2.2.1. Second dose receipt of mRNA-1273

The primary outcome was a dichotomous variable indicating whether patients who received a first dose of mRNA-1273 received a second dose of mRNA-1273 "on-time", defined as receiving the dose between 24 and 42 days after the first dose, per CDC guidelines prior to April 2022 [20].

2.2.2. Third dose receipt of mRNA-1273

On August 13, 2021, the CDC recommended that adult patients who were moderately or severely immunocompromised and had completed two doses of mRNA vaccine should receive a third primary series dose. The primary outcome was a dichotomous variable indicating whether immunocompromised patients (determined based on pharmacy claims data) who received their first two doses of mRNA-1273 at Walgreens received a third dose of mRNA-1273, regardless of the timing of the first two doses.

2.2.3. Early vs. late adopter status

On March 29, 2021, Kansas, Louisiana, North Dakota, Ohio, Oklahoma, and Texas announced the expansion of COVID-19 vaccinations from a phased allocation to all eligible adults. To explore the characteristics of early vs. late adopters of mRNA-1273, 5 of these states were analyzed independently (Walgreens does not operate in North Dakota). Patients who received their first dose of mRNA-1273 between March 29 and August 15, 2021 were considered early adopters, while those who were vaccinated on or after August 16, 2021 were considered late adopters. This cut-off point was determined by examining trends in the data, which demonstrated a clear wave of patients who were vaccinated on or prior to the August 15 timeframe. Excluded from the analysis were patients who received their first dose before March 29, which is when US states made the vaccine available to all adults in the general public.

2.3. Data analysis

This study followed Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines. Patient characteristics (age, gender, race/ethnicity, distance to vaccination site, RUCA, SVI, and other community-level variables) were summarized using descriptive statistics for all patients receiving their first dose of mRNA-1273 and stratified by each outcome. Multivariable logistic regressions were conducted using SAS V9 (Research Triangle Park, North Carolina) to examine associations between patient characteristics, including individual-level and population-level factors, and the dose completion outcome in question. The models were re-run after manually removing variables that were not significant ($p > 0.05$) and those with multicollinearity ($R > 0.70$). In situations where variables displayed multicollinearity, the variable with the strongest univariate association was kept in the model. This method yielded the best model fit based on the R-Square estimate.

3. Results

A total of 4,870,915 adult patients received an initial dose of mRNA-1273 at the pharmacy and were eligible for a second mRNA-1273 dose. Patients were 57.0% White (not Hispanic/Latino), 52.6% female, and averaged 49.4 years of age (range from 18 to 100 years) (Tables 1 and 2). Among patients who received a first dose of mRNA-1273, 84.9% (n = 4,137,382) went on to receive a second dose at any point in time and of these, 96.0% received the second dose on-time (n = 3,970,906). The overall mean length of time between doses was 30.5 days; patients that received a second dose at any time were 58.9% White (not Hispanic/Latino), 52.6% female, and averaged 49.0 years of age (Tables 1 and 2).

Factors associated with on-time receipt of the second dose (between 24 and 42 days after the first dose) are shown in Table 3. Notable associations (odds ratios [OR] < 0.90 or > 1.10) included older age (in comparison to 18–21 years, 22–34 years OR 1.178, 95% confidence interval [CI] 1.165 – 1.191; 35–54 years OR 1.646, 95% CI 1.628 – 1.664; 55–64 years OR 2.042, 95% CI 2.018 – 2.067; and ≥ 65 years OR 2.167, 95% CI 2.142 – 2.192), race/ethnicity (in comparison to White [not Hispanic/Latino], Asian OR 1.239, 95% CI 1.222 – 1.257; not Black or African American OR 0.711, 95% CI 0.705 – 0.716; not Hispanic/Latino OR 0.792, 95% CI 0.786 – 0.798; not Native Indian or Alaska Native OR 0.772, 95% CI 0.752 – 0.792, not Native Hawaiian or Other Pacific Islander OR 0.713, 95% CI 0.685 – 0.742; Table 3), and not traveling over 10 miles for the first dose (in comparison to < 10 miles, 50–99 miles OR 0.778, 95% CI 0.765 – 0.792, 100–149 miles OR 0.703, 95% CI 0.684 – 0.722, 150–199 miles OR 0.636, 95% CI 0.613 – 0.659, 200–249 miles OR 0.583, 95% CI 0.553 – 0.570, and 250 + miles OR 0.561, 95% CI 0.553 – 0.570). Regarding community-level variables, for every 5% increase in the percent of the population without health insurance based on ZCTA of residence, the odds of receiving a second dose of mRNA-1273 on-time dropped by 14.1% (OR 0.859, 95% CI 0.856 – 0.861). Patients residing in medium–high and high SVI areas had decreased odds of receiving their second dose on-time compared to those in low SVI areas (OR 0.885, 95% CI 0.877 – 0.892 and OR 0.857, 95% CI 0.847 – 0.867, respectively).

A total of 39,819 patients were determined to be eligible to receive a third primary series dose of mRNA-1273 as of August 13, 2021 (moderately or severely immunocompromised based on pharmacy claims data and had completed their first two doses); 51.0% (n = 20,316) of those patients received a third dose of mRNA-1273. Patients who received their third dose were 76.1% White (not Hispanic/Latino), 61.8% female, and averaged 61.4 years of age (Tables 1 and 2).

Factors associated with receipt of the third dose among eligible immunocompromised patients are shown in Table 4. Notable associations (OR < 0.90 or > 1.10) included older age (in comparison to 18–21 years, 22–34 years OR 1.395, 95% CI 1.087 – 1.792; 35–54 years OR 1.793, 95% CI 1.408 – 1.284; 55–64 years OR 2.278, 95% CI 2.787 – 2.904; and ≥ 65 years OR 2.493, 95% CI 1.959 – 3.171) and race/ethnicity (in comparison to White [not Hispanic/Latino], not Hispanic/Latino OR 0.869, 95% CI 0.795 – 0.951). Regarding community-level variables, patients residing in a small-town area had increased odds of receiving a third dose of mRNA-1273 compared to those residing in a metropolitan area (OR 1.154, 95% CI 1.038 – 1.283).

A total of 440,736 patients were included in the adopter status analysis. Early adopters (i.e., those who received their first dose of

Table 1
Patient Characteristics by Number of Doses Received (Categorical Variables).

	Dose 1		Dose 2 (Any time)		Dose 2 (On-time)		Dose 3 (Immunocompromised only)	
	Frequency (N = 4,870,915)	Percent	Frequency (N = 4,137,382)	Percent	Frequency (N = 3,970,906)	Percent	Frequency (N = 20,316)	Percent
Patient - Level Characteristics								
Sex								
Female	2,563,465	52.63	2,177,599	52.63	2,093,180	52.71	12,558	61.81
Male	2,307,450	47.37	1,959,783	47.37	1,877,726	47.29	7,758	38.19
Age Category								
18–21 years	203,639	4.18	159,995	3.87	149,108	3.76	106	0.52
22–34 years	1,148,470	23.58	933,528	22.56	878,107	22.11	1,195	5.88
35–54 years	1,552,022	31.86	1,327,976	32.10	1,271,919	32.03	4,723	23.25
55–64 years	796,281	16.35	698,288	16.88	675,554	17.01	4,344	21.38
65 + years	1,170,503	24.03	1,017,595	24.60	996,218	25.09	9,948	48.97
Race/Ethnicity								
White (not Hispanic/ Latino)	2,774,316	56.96	2,435,983	58.88	2,351,043	59.21	15,453	76.06
Hispanic or Latino	771,809	15.85	663,037	16.03	631,423	15.90	2,054	10.11
Black or African American	528,561	10.85	437,903	10.58	409,892	10.32	1,441	7.09
Asian	230,751	4.74	209,457	5.06	204,649	5.15	544	2.68
American Indian or Alaskan Native	37,991	0.78	31,928	0.77	30,201	0.76	118	0.58
Native Hawaiian or Pacific Islander	14,692	0.30	12,268	0.30	11,596	0.29	32	0.16
Other	71,627	1.47	62,593	1.51	59,620	1.50	207	1.02
Unknown	441,168	9.06	284,213	6.87	272,482	6.86	467	2.30
Distance from the patient's address to the location of their first dose								
<10 miles	3,689,453	75.81	3,161,051	76.48	3,030,245	76.38	14,965	73.75
10–49 miles	946,589	19.45	794,880	19.23	768,202	19.36	4,494	22.15
50–99 miles	76,769	1.58	61,355	1.48	59,145	1.49	345	1.7
100–149 miles	29,120	0.60	22,764	0.55	21,737	0.55	122	0.6
150–199 miles	15,712	0.32	11,898	0.29	11,244	0.28	51	0.25
200–249 miles	10,979	0.23	8,148	0.20	7,684	0.19	27	0.13
250 + miles	97,957	2.01	73,062	1.77	69,283	1.75	287	1.41
Community - Level Characteristics								
Social Vulnerability Index Category								
Low (0-0.25)	1,218,617	25.02	1,070,109	25.86	1,038,946	26.16	6,641	32.69
Med-Low (0.25-0.5)	1,612,655	33.11	1,384,670	33.47	1,334,719	33.61	6,972	34.32
Med-High (0.5-0.75)	1,440,120	29.57	1,198,231	28.96	1,141,329	28.74	5,284	26.01
High (0.75+)	599,523	12.31	484,372	11.71	455,912	11.48	1,419	6.98
Rural-Urban Commuting Area								
Metropolitan	4,091,334	84.00	3,498,484	84.56	3,363,086	84.69	17,337	85.34
Micropolitan	466,484	9.58	381,402	9.22	362,200	9.12	1,689	8.31
Small town	195,755	4.02	160,398	3.88	152,657	3.84	829	4.08
Rural areas	117,342	2.41	97,098	2.35	92,963	2.34	461	2.27

Table 2
Patient Characteristics by Number of Doses Received (Continuous Variables).

	Dose 1 (N = 4,870,915)			Dose 2 (Any time; N = 4,137,382)			Dose 2 (On-time; N = 3,970,906)			Dose 3 (Immunocompromised only; N = 20,316)		
Variable	**Frequency**	**Mean (SD)**	**Median**	**Frequency**	**Mean (SD)**	**Median**	**Frequency**	**Mean (SD)**	**Median**	**Frequency**	**Mean (SD)**	**Median**
Patient - Level Characteristics												
Age (years)	4,870,915	49.42 (19.09)	48.00	4,137,382	49.89 (18.87)	49.00	3,970,906	50.17 (18.87)	50.00	20,316	61.40 (15.49)	64.00
Community - Level Characteristics												
Census Data												
Sex Ratio (males per 100 females)	4,869,757	97.39 (122.67)	95.50	4,136,367	97.27 (119.21)	95.40	3,969,931	97.25 (113.02)	95.40	20,313 (97.03)	97.03 (117.09)	95.20
Unemployment Rate (%)	4,868,398	5.43 (3.67)	4.58	4,135,189	5.42 (3.70)	4.54	3,968,787	5.41 (3.71)	4.52	20,308	5.19 (3.66)	4.22
Speaks English Less Than Very Well (%)	4,870,072	9.87 (16.14)	4.20	4,136,648	10.12 (16.58)	4.30	3,970,201	10.16 (16.68)	4.30	20,316	8.95 (16.50)	3.70
Foreign Born (%)	4,870,072	11.74 (11.31)	8.10	4,136,648	11.86 (11.37)	8.20	3,970,201	11.87 (11.38)	8.20	20,316	10.22 (9.25)	7.60
Disabled (%)	4,869,686	12.98 (5.14)	12.00	4,136,307	12.89 (5.16)	11.90	3,969,865	12.86 (5.15)	11.90	20,313	12.72 (5.44)	11.50
Per Capita Income ($)	4,868,268	36,264.46 (17,288.51)	32,542.00	4,135,068	36,613.06 (17,539.68)	32907.00	3,968,674	36,758.89 (17,646.50)	33,115.00	20,308	39,426.62 (19,039.27)	35,435.00
Health Insurance Coverage of Community												
Covered by Public Health Insurance (%)	4,869,069	35.92 (12.56)	34.50	4,135,784	35.81 (12.64)	34.30	3,969,359	35.76 (12.65)	34.20	20,311	34.99 (12.95)	32.50
No Health Insurance (%)	4,869,069	7.92 (5.55)	6.50	4,135,784	7.74 (5.44)	6.40	3,969,359	7.68 (5.40)	6.30	20,311	6.49 (4.12)	5.50
Education Level of Community												
At Least High School Education	4,869,859	88.83 (8.05)	90.90	4,136,467	88.95 (8.01)	91.00	3,970,024	89.01 (7.99)	91.10	20,316	90.53 (7.06)	92.50
At Least Bachelor's degree	4,869,859	34.26 (17.91)	30.20	4,136,467	34.70 (17.99)	31.00	3,970,024	34.89 (18.03)	31.10	20,316	37.75 (19.00)	34.70
Some High School, No Diploma	4,869,859	6.30 (4.03)	5.50	4,136,467	6.20 (3.99)	5.40	3,970,024	6.16 (3.98)	5.40	20,316	5.45 (3.89)	4.70
Age of Community												
Age < 18 years	4,870,072	21.90 (4.99)	22.00	4,136,648	21.84 (4.96)	22.00	3,970,201	21.81 (4.96)	22.00	20,316	21.53 (4.73)	21.80
Age $\geq$ 65 years	4,870,072	16.68 (6.31)	16.20	4,136,648	16.74 (6.32)	16.20	3,970,201	16.77 (6.32)	16.20	20,316	17.81 (6.76)	17.10
Race/Ethnicity of Community												
Hispanic or Latino	4,870,072	18.59 (23.99)	8.90	4,136,648	18.69 (24.22)	8.90	3,970,201	18.67 (24.27)	8.90	20,316	16.15 (23.28)	7.50
White (not Hispanic/ Latino)	4,870,072	61.62 (27.99)	69.70	4,136,648	61.76 (28.03)	69.90	3,970,201	61.88 (28.01)	70.00	20,316	67.14 (25.54)	74.70
Black or African American	4,870,072	11.60 (16.85)	4.70	4,136,648	11.28 (16.50)	4.60	3,970,201	11.15 (16.37)	4.60	20,316	9.10 (14.10)	3.60
American Indian or Alaskan Native	4,870,072	0.48 (2.16)	0.10	4,136,648	0.46 (2.04)	0.10	3,970,201	0.46 (2.04)	0.10	20,316	0.39 (1.53)	0.10
Asian	4,870,072	4.81 (7.46)	2.20	4,136,648	4.93 (7.58)	2.30	3,970,201	4.96 (7.62)	2.30	20,316	4.63 (6.19)	2.4
Native Hawaiian or Pacific Islander	4,870,072	0.10 (0.65)	0.00	4,136,648	0.09 (0.62)	0.00	3,970,201	0.09 (0.62)	0.00	20,316	0.05 (0.27)	0.00
Other	4,870,072	0.30 (0.74)	0.10	4,136,648	0.30 (0.74)	0.10	3,970,201	0.30 (0.74)	0.10	20,316	0.25 (0.55)	0.10

Table 3
Logistic Regression for On-time Second Dose Receipt*.

Model Parameters	Odds Ratio	95% Confidence Interval	
Individual-Level Parameters			
Distance from the patient's address to the location of first dose			
<10 miles	1.000	n/a	n/a
10–49 miles	0.981	0.975	0.987
50–99 miles	0.778	0.765	0.792
100–149 miles	0.703	0.684	0.722
150–199 miles	0.636	0.613	0.659
200–249 miles	0.583	0.559	0.608
250 + miles	0.561	0.553	0.570
Sex			
Male	1.000	n/a	n/a
Female	1.032	1.027	1.037
Age			
18–21 years	1.000	n/a	n/a
22–34 years	1.178	1.165	1.191
35–54 years	1.646	1.628	1.664
55–64 years	2.042	2.018	2.067
≥65 years	2.167	2.142	2.192
Race/Ethnicity			
White (not Hispanic/Latino)	1.000	n/a	n/a
American Indian or Alaska Native	0.772	0.752	0.792
Asian	1.239	1.222	1.257
Black or African American	0.711	0.705	0.716
Hispanic/Latino	0.792	0.786	0.798
Native Hawaiian or Other Pacific Islander	0.713	0.685	0.742
Other	0.868	0.850	0.885
Unknown	0.280	0.278	0.282
Community-Level Parameters			
Census Data			
Per capita income ($10,000 incremental increase)	1.010	1.007	1.013
Percentage of population "disabled" (5% incremental increase)	0.968	0.965	0.971
Percentage of population "foreign born" (5% incremental increase)	1.026	1.024	1.027
Percentage of population "speaks English less than very well" (5% incremental increase)	1.063	1.061	1.064
Percentage of population with no health insurance (5% incremental increase)	0.859	0.856	0.861
Percentage of population with at least a Bachelor's degree (5% incremental increase)	1.004	1.003	1.006
Rural-Urban Commuting Area			
Metropolitan	1.000	n/a	n/a
Micropolitan	0.921	0.913	0.928
Small town	0.949	0.938	0.960
Rural areas	0.992	0.977	1.008
Social Vulnerability Index Category			
Low (0–0.25)	1.000	n/a	n/a
Med-Low (0.25–0.5)	0.957	0.951	0.964
Med-High (0.5–0.75)	0.885	0.877	0.892
High (0.75+)	0.857	0.847	0.867

* On-time second dose receipt n = 3,970,906 out of n = 4,870,915 eligible for the second dose.

Table 4
Logistic Regression for Third Dose Receipt among Immunocompromised patients*.

Model Parameters	Odds Ratio	95% Confidence Interval	
Individual-Level Parameters			
Distance from the patient's address to the location of first dose			
<10 miles	1.000	n/a	n/a
10–49 miles	0.975	0.928	1.025
50–99 miles	1.032	0.881	1.208
100–149 miles	0.928	0.717	1.201
150–199 miles	1.236	0.808	1.892
200–249 miles	1.672	0.894	3.127
250 + miles	0.680	0.581	0.796
Age			
18–21 years	1.000	n/a	n/a
22–34 years	1.395	1.087	1.792
35–54 years	1.793	1.408	2.284
55–64 years	2.278	1.787	2.904
65 + years	2.493	1.959	3.171
Race/Ethnicity			
White (not Hispanic/Latino)	1.000	n/a	n/a
American Indian or Alaska Native	1.089	0.828	1.432
Asian	0.992	0.871	1.130
Black or African American	0.968	0.893	1.049
Hispanic or Latino	0.869	0.795	0.951
Native Hawaiian or Other Pacific Islander	0.983	0.591	1.636
Other	0.726	0.599	0.879
Unknown	0.134	0.121	0.148
Community-Level Parameters			
Census Data			
Per capita income ($10,000 incremental increase)	1.034	1.010	1.059
Percentage of population "speaks English less than very well" (5% incremental increase)	1.054	1.044	1.064
Percentage of population with no health insurance (5% incremental increase)	0.971	0.944	0.999
Percentage of population with at least a Bachelor's degree (5% incremental increase)	1.022	1.010	1.033
Rural-Urban Commuting Area			
Metropolitan	1.000	n/a	n/a
Micropolitan	0.947	0.879	1.021
Small town	1.154	1.038	1.283
Rural areas	0.970	0.848	1.111

* Third dose receipt n = 20,316 out of n = 39,819 eligible for the third dose.

mRNA-1273 before August 16, 2021) accounted for 60.6% (n = 267,061) of patients. Patients classified as early adopters were 39.9% White (not Hispanic/Latino), 49.1% female, and averaged 42.6 years of age (Table 5). Factors associated with early adoption of mRNA-1273 vaccine among eligible patients are shown in Table 6. Notable associations (OR < 0.90 or > 1.10) included older age (in comparison to 18–21 years, 35–54 years OR 1.178, 95% CI 1.148 – 1.208; 55–64 years OR 1.569, 95% CI 1.523 – 1.617; and ≥ 65 years OR 1.808, 95% CI 1.749 – 1.868) and race/ethnicity (in comparison to White [not Hispanic/Latino], Asian OR 1.471, 95% CI 1.415 – 1.529; not Black or African American OR 0.823, 95% CI 0.808 – 0.838; and not Native Hawaiian or Other Pacific Islander OR 0.835, 95% CI 0.742 – 0.939). Compared patients residing in a metropolitan area, those residing in a micropolitan area (OR 0.748, 95% CI 0.732 – 0.765), small town (OR 0.796, 95% CI 0.765 – 0.828), or rural area (OR 0.655, 95% CI 0.611 – 0.702) had decreased odds of early mRNA-1273 vaccine adoption.

4. Discussion

This study of >4.8 million mRNA-1273 vaccine recipients from Walgreens pharmacies described characteristics of patients by number of doses completed and time of administration. The mean age for the first and second primary series dose was similar at approximately 50 years and female patients represented a slight majority. Females also accounted for just over 60% of those who received a third dose; however, the mean age was substantially higher at 61 years. The higher age at receipt of a third dose is expected as CDC guidelines recommended that only adult patients who were moderately or severely immunocompromised should receive a third primary series dose.

Our findings revealed disparities among patients regarding the on-time receipt of the second dose. The majority of patients who received the first dose returned for the second dose (81.5%) within the recommended timeframe. Patient characteristics associated with receiving the second dose on-time included being older, with a linear relationship between increasing age and greater on-time receipt, identifying as Asian or White (not Hispanic/Latino), and not traveling over 10 miles for the first dose., Residing in areas with

Table 5
Patient Characteristics by Adopter Status*.

Categorical Variables	Early Adopter		Late Adopter	
	Frequency (n = 267,061)	Percent	Frequency (n = 173,675)	Percent
Patient - Level Characteristics				
Sex				
Female	130,994	49.05	85,122	49.01
Male	136,067	50.95	88,553	50.99
Age Category				
18–21 years	16,206	6.07	12,014	6.92
22–34 years	81,656	30.58	65,212	37.55
35–54 years	105,361	39.45	66,517	38.30
55–64 years	38,112	14.27	18,772	10.81
65 + years	25,726	9.63	11,160	6.43
Race/Ethnicity				
White (not Hispanic/ Latino)	106,543	39.89	63,698	36.68
Hispanic or Latino	81,481	30.51	50,113	28.85
Black or African American	48,885	18.3	35,491	20.44
Asian	10,636	3.98	3,985	2.29
American Indian or Alaskan Native	2,991	1.12	1,901	1.09
Native Hawaiian or Pacific Islander	676	0.25	491	0.28
Other	3,729	1.40	2,494	1.44
Unknown	12,120	4.54	15,502	8.93
Distance from the patient's address to the location of their first dose				
<10 miles	214,820	80.53	137,331	79.12
10–49 miles	37,902	14.21	26,793	15.44
50–99 miles	2,591	0.97	2,163	1.25
100–149 miles	1,518	0.57	1,110	0.64
150–199 miles	1,295	0.49	942	0.54
200–249 miles	1,218	0.46	900	0.52
250 + miles	7,413	2.78	4,345	2.50
Community – Level Characteristics				
Social Vulnerability Index Category				
Low (0-0.25)	41,667	15.60	21,473	12.36
Med-Low (0.25-0.5)	73,555	27.54	45,428	26.16
Med-High (0.5-0.75)	86,227	32.29	59,833	34.45
High (0.75+)	65,612	24.57	46,941	27.03
Rural-Urban Commuting Area				
Metropolitan	237,252	88.84	146,947	84.61
Micropolitan	21,841	8.18	19,580	11.27
Small town	6,255	2.34	5,351	3.08
Rural areas	1,713	0.64	1,797	1.03

Continuous Variables	Frequency	Mean (SD)	Median	Frequency	Mean (SD)	Median
Patient - Level Characteristics						
Age (years)	267,061	42.57 (15.67)	41.00	173,675	39.50 (14.61)	37.00
Community – Level Characteristics						
Census Data						
Sex Ratio (males per 100 females)	267,020	98.08 (16.37)	96.40	173,640	98.11 (15.88)	96.50
Unemployment Rate (%)	266,997	5.32 (2.49)	4.83	173,628	5.44 (2.61)	4.93
Speaks English Less Than Very Well (%)	267,022	11.54 (11.46)	7.70	173,643	11.21 (11.29)	7.60
Foreign Born (%)	267,022	15.39 (15.72)	12.90	173,643	14.54 (11.65)	11.60
Disabled (%)	267,013	11.96 (4.71)	11.20	173,638	12.51 (4.83)	11.70
Per Capita Income ($)	266,999	31,852.79 (12,723.44)	29,720.00	173,627	30,567.20 (12,175.79)	28,290.00
Health Insurance Coverage of Community						
Covered by Public Health Insurance (%)	267,008	30.65 (11.03)	30.00	173,632	32.03 (10.83)	31.50
No Health Insurance (%)	267,008	15.52 (8.53)	13.80	173,632	15.88 (8.42)	14.30
Education Level of Community						
At Least High School Education	267,022	84.76 (10.88)	87.80	173,643	84.19 (10.72)	87.40
At Least Bachelor's degree	267,022	29.45 (16.73)	26.40	173,643	27.22 (15.87)	24.30
Some High School, No Diploma	267,022	8.06 (4.97)	7.10	173,643	8.48 (4.88)	7.70
Age of Community						
Age < 18 years	267,022	25.44 (4.93)	25.90	173,643	25.39 (4.88)	25.70
Age $\geq$ 65 years	267,022	12.73 (4.82)	12.20	173,643	13.09 (4.87)	12.60
Race/Ethnicity of Community						
Hispanic or Latino	267,022	30.03 (24.86)	23.10	173,643	29.29 (24.36)	22.80
White (not Hispanic/Latino)	267,022	45.13 (25.15)	47.90	173,643	45.46 (26.05)	48.20
Black or African American	267,022	16.42 (16.74)	11.10	173,643	17.50 (17.78)	11.70
American Indian or Alaskan Native	267,022	0.65 (2.69)	0.20	173,643	0.72 (2.97)	0.20
Asian	267,022	5.06 (6.80)	2.50	173,643	4.34 (6.09)	2.10
Native Hawaiian or Pacific Islander	267,022	0.06 (0.21)	0.00	173,643	0.06 (0.24)	0.00
Other	267,022	0.24 (0.43)	0.10	173,643	0.23 (0.44)	0.10

* Patients who received their first dose of mRNA-1273 between March 29 and August 15, 2021 were considered early adopters, while those who were vaccinated on or after August 16, 2021 were considered late adopters. Data only available for Kansas, Louisiana, Ohio, Oklahoma, and Texas.

Table 6
Logistic Regression for Early Adopter Status*.

Model Parameters	Odds Ratio	95% Confidence Interval	
Individual-Level Parameters			
Distance from the patient's address to the location of first dose			
<10 miles	1.000	n/a	n/a
10–49 miles	1.000	0.982	1.018
50–99 miles	0.920	0.868	0.976
100–149 miles	1.009	0.932	1.092
150–199 miles	0.961	0.882	1.046
200–249 miles	0.935	0.856	1.021
250 + miles	1.11	1.068	1.154
Age			
18–21 years	1.000	n/a	n/a
22–34 years	0.910	0.886	0.934
35–54 years	1.178	1.148	1.208
55–64 years	1.569	1.523	1.617
65 + years	1.808	1.749	1.868
Race/Ethnicity			
White (not Hispanic/Latino)	1.000	n/a	n/a
American Indian or Alaska Native	1.003	0.945	1.064
Asian	1.471	1.415	1.529
Black or African American	0.823	0.808	0.838
Hispanic or Latino	1.019	1.002	1.036
Native Hawaiian or Other Pacific Islander	0.835	0.742	0.939
Other	0.874	0.830	0.921
Unknown	0.494	0.481	0.507
Community-Level Parameters			
Census Data			
Per capita income ($10,000 incremental increase)	0.939	0.929	0.950
Percentage of population "foreign born" (5% incremental increase)	0.990	0.984	0.997
Percentage of population "speaks English less than very well" (5% incremental increase)	1.049	1.040	1.058
Percentage of population with no health insurance (5% incremental increase)	0.943	0.936	0.951
Percentage of patients with at least a high school diploma or equivalent (5% incremental increase)	0.982	0.973	0.990
Percentage of patients with at least a bachelor's degree (5% incremental increase)	1.064	1.058	1.069
Unemployment rate (5% incremental increase)	1.024	1.010	1.039
Rural-Urban Commuting Area			
Metropolitan	1.000	n/a	n/a
Micropolitan	0.748	0.732	0.765
Small town	0.796	0.765	0.828
Rural areas	0.655	0.611	0.702
Social Vulnerability Index Category			
Low (0–0.25)	1.000	n/a	n/a
Med-Low (0.25–0.5)	0.961	0.939	0.983
Med-High (0.5–0.75)	1.009	0.983	1.036
High (0.75+)	0.983	0.950	1.018

* Early adopters n = 267,061 out of n = 440,736.

high rates of no medical insurance and with a medium–high or high SVI rating were associated with not receiving the second dose on-time.

The pharmacy administered the first dose of mRNA-1273 to a national cohort that was broadly representative of the racial and ethnic makeup of the US: Hispanic or Latino (15.8% vs 18.9% US), Black or African American (10.9% vs. 12.6% US), and Asian (4.7% vs. 5.9% US). On the other hand, patients identifying as Hispanic or Latino / Black or African American had reduced odds of receiving the second dose on-time as compared to White (not Hispanic/Latino) patients, suggesting that factors other than accessibility contributed to lower rates among these patients. These findings are in-line with the results of a systematic review that found low-to-moderate evidence of lower H1N1 influenza vaccine uptake among Black or African American individuals, as well as those with low socioeconomic and educational status [21]. A recent study by the CDC also found ethnic and socioeconomic disparities among COVID-19 vaccination coverage and similarly concluded that the disparities were not attributable to access [14].

Although some patients were late to receive the second dose, the vast majority of our population (84.9%) completed the 2-dose vaccine series. This COVID-19 vaccine series completion is substantially higher than series completion rates reported for adults receiving hepatitis A (25.0%–43.6%), hepatitis B (41.4%-62.6%), and herpes zoster (70.4%) vaccines [12–13]. There are likely many factors that contributed to the high mRNA-1273 series completion rates seen here, such as the presence of the COVID-19 pandemic, broad vaccine accessibility during the pandemic, including thousands of pharmacies, elimination of out-of-pocket cost as a barrier, the expansive COVID-19 vaccine education and promotion campaign, and employment mandates. Further research is warranted to fully understand the factors that contributed to the successful series completion observed here. More generally, by understanding the factors associated with multi-dose vaccine regimens, providers can reach out to populations associated with not being vaccinated or not completing a vaccination series. Some of these factors can be inferred based on where a patient lives by utilizing publicly available datasets such as the ACS, RUCA, and SVI, while others are associated with the patients themselves and should be easily obtainable by most providers.

Our study also examined characteristics of those who were defined as early or late adopters of the first dose of mRNA-1273 vaccine in specific states following the expansion of COVID-19 vaccinations from a phased allocation to all eligible adults. Similar to findings by Kriss and colleagues [22], we found that early adoption (60.6% of patients) was associated with being older, Asian or White (not Hispanic/Latino), and residing in a metropolitan area. Future studies are needed to understand the disparities among early and late adoption of vaccination during a pandemic.

This study had several strengths, most notably the large, nationally representative sample of 4,870,915 individuals. The high volume of mRNA-1273 vaccine provided by pharmacists during the study period emphasizes the importance of pharmacists as care providers, especially in disadvantaged communities where access to other forms of care may be difficult. Outreach and easy access provided at pharmacy locations could be especially useful in encouraging patients to receive vaccines in a timely manner. Our study also had several limitations. While there were 3 COVID-19 vaccines approved for use in the US during the study period, this study was limited to the examination of only one of these vaccines (mRNA-1273); Patients were not surveyed at the time of vaccination about important social determinants of health such as their income, education level, and vaccine hesitancy. While some of these data can be inferred from the community they live in, this is less accurate than individual-level data. Additionally, the third dose of the vaccine was limited to those patients who were considered immunocompromised as per the CDC during that time. Without access to electronic health records/medical claims data and diagnosis codes, this information was inferred based on pharmacy claims data in the present study and is subject to inaccuracy due to off-label prescribing, and in some cases multiple uses for the same drug. This study was limited to only Walgreens retail pharmacies located in the US, and is not representative of other countries' vaccination efforts. The data are unable to account for patients who received a second or booster dose of mRNA-1273 outside of a US Walgreens pharmacy and may be underestimating vaccination rates for secondary and booster doses.

Findings from this study of >4.8 million mRNA-1273 vaccine recipients in the US found racial/ethnic and socioeconomic disparities in vaccine uptake. Similar disparities have been reported in previous research, suggesting the need for further study into vaccination barriers and facilitators within these populations [10,23,24]. On the other hand, the vaccine series completion rates observed here are substantially higher than those reported in past research on hepatitis and herpes zoster [12–13]. The novel approaches to facilitate series completion during a pandemic, as well as broad access and no patient out-of-pocket cost, should be further studied and employed by future vaccination campaigns. Finally, the present study demonstrates the capacity for a large national retail pharmacy to play a principal role in administering vaccines in the event of a pandemic [7]. Given proper training and education, pharmacists and pharmacy technicians have demonstrated that they can implement mass vaccination campaigns safely, effectively, and rapidly, and can therefore provide critical support to maintaining public health.

Data availability

The authors do not have permission to share data.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Erin Roberts-McCarthy, MPH reports financial support was provided by Moderna Inc. Erin Roberts-McCarthy, MPH reports a relationship with Walgreen Co that includes: employment and equity or stocks. Philip O. Buck, PhD, MPH reports a relationship with Moderna Inc that includes: employment and equity or stocks. Renae L. Smith-Ray, PhD reports a relationship with Walgreen Co. that includes: employment and equity or stocks. Nicolas Van de Velde reports a relationship with Moderna Inc that includes: employment and equity or stocks. Tanya Singh, MPH reports a relationship with Walgreen Co that includes: employment and equity or stocks. James Mansi, PhD reports a relationship with Moderna Inc that includes: employment and equity or stocks. Amy Shah, MPH reports a relationship with Walgreen Co. that includes: employment and equity or stocks. Michael Taitel, PhD reports a relationship with Walgreen Co that includes: employment and equity or stocks.

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For more information on this research, please contact research@walgreens.com.

Appendix A. American community survey variables considered.

Name	Geographic Area (ZCTA)
DP02_0061PE	Percent - EDUCATIONAL ATTAINMENT - Population 25 years and over – 9th to 12th grade, no diploma
DP02_0067PE	Percent - EDUCATIONAL ATTAINMENT - Population 25 years and over - High school graduate or higher
DP02_0068PE	Percent - EDUCATIONAL ATTAINMENT - Population 25 years and over - Bachelor's degree or higher
DP02_0072PE	Percent - DISABILITY STATUS OF THE CIVILIAN NONINSTITUTIONALIZED POPULATION - Total Civilian Noninstitutionalized Population - With a disability
DP02_0094PE	Percent - PLACE OF BIRTH - Total population - Foreign born
DP02_0115PE	Percent - LANGUAGE SPOKEN AT HOME - Population 5 years and over - Language other than English - Speak English less than very well
DP03_0088E	Estimate - INCOME AND BENEFITS (IN 2020 INFLATION-ADJUSTED DOLLARS) - Per capita income (dollars)
DP03_0098PE	Percent - HEALTH INSURANCE COVERAGE - Civilian noninstitutionalized population - With health insurance coverage - With public coverage
DP03_0099PE	Percent - HEALTH INSURANCE COVERAGE - Civilian noninstitutionalized population - No health insurance coverage
DP03_0109PE	Percent - HEALTH INSURANCE COVERAGE - Civilian noninstitutionalized population 19 to 64 years - In labor force - Unemployed
DP05_0004E	Estimate - SEX AND AGE - Total population - Sex ratio (males per 100 females)
DP05_0019PE	Percent - SEX AND AGE - Total population - Under 18 years
DP05_0024PE	Percent - SEX AND AGE - Total population – 65 years and over
DP05_0037PE	Percent - RACE - Total population - One race - White
DP05_0038PE	Percent - RACE - Total population - One race - Black or African American
DP05_0039PE	Percent - RACE - Total population - One race - American Indian and Alaska Native
DP05_0044PE	Percent - RACE - Total population - One race - Asian
DP05_0052PE	Percent - RACE - Total population - One race - Native Hawaiian and Other Pacific Islander
DP05_0057PE	Percent - RACE - Total population - One race - Some other race
DP05_0071PE	Percent - HISPANIC OR LATINO AND RACE - Total population - Hispanic or Latino (of any race)

Appendix B.1. Rural-urban commuting area codes.

1	Metropolitan area core: primary flow within an urbanized area (UA)
2	Metropolitan area high commuting: primary flow 30% or more to a UA
3	Metropolitan area low commuting: primary flow 10% to 30% to a UA
4	Micropolitan area core: primary flow within an Urban Cluster of 10,000 to 49,999 (large UC)
5	Micropolitan high commuting: primary flow 30% or more to a large UC
6	Micropolitan low commuting: primary flow 10% to 30% to a large UC
7	Small town core: primary flow within an Urban Cluster of 2,500 to 9,999 (small UC)

(*continued on next page*)

8	Small town high commuting: primary flow 30% or more to a small UC
9	Small town low commuting: primary flow 10% to 30% to a small UC
10	Rural areas: primary flow to a tract outside a UA or UC
99	Not coded: Census tract has zero population and no rural–urban identifier information

Appendix B.2. Collapsed rural-urban commuting area classifications.

Metropolitan
Metropolitan area core: primary flow within an urbanized area (UA)
Metropolitan area high commuting: primary flow 30% or more to a UA
Metropolitan area low commuting: primary flow 10% to 30% to a UA
Micropolitan
Micropolitan area core: primary flow within an Urban Cluster of 10,000 to 49,999 (large UC)
Micropolitan high commuting: primary flow 30% or more to a large UC
Micropolitan low commuting: primary flow 10% to 30% to a large UC
Small Town
Small town core: primary flow within an Urban Cluster of 2,500 to 9,999 (small UC)
Small town high commuting: primary flow 30% or more to a small UC
Small town low commuting: primary flow 10% to 30% to a small UC
Rural
Rural areas: primary flow to a tract outside a UA or UC

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