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Vaccine 39 (2021) 7074–7081

Contents lists available at ScienceDirect

Vaccine

journal homepage: www.elsevier.com/locate/vaccine

Changes in COVID-19 vaccine acceptance rate among recovered critically Ill patients: A 12-month follow-up study

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ARTICLE INFO

Article history:
Received 23 December 2020
Received in revised form 17 August 2021
Accepted 9 October 2021
Available online 25 October 2021

Keywords:
COVID-19 vaccination
Mechanical ventilation
Pandemic: vaccine uptake

ABSTRACT

Introduction: We surveyed a cohort of patients who recovered from severe SARS-CoV-2 infection to determine the COVID-19 vaccination rate. We also compared the willingness to accept COVID-19 vaccine before and after its availability to assess changes in perception and attitude towards vaccination.
Materials and Methods: Recovered patients with severe hypoxemic respiratory failure from SARS-CoV-2 infection treated in the ICU at Grady Memorial Hospital, Atlanta, Georgia between April 1, 2020, and June 30, 2020 were followed up over a 1-year period to assess vaccine acceptability and acceptance rates, and changes in perception towards COVID-19 vaccination before and after vaccine availability.
Results: A total of 98 and 93 patients completed the initial and follow up surveys respectively. During the initial survey, 41% of the patients intended to receive vaccination, 46% responded they would not accept a vaccine against COVID-19 even if it were proven to be 'safe and effective 'and 13% undecided. During the follow up survey, 44% of the study cohort had received at least one dose of a COVID-19 vaccine. Major reasons provided by respondents for not accepting COVID-19 vaccine were lack of trust in the effectiveness of the vaccine, pharmaceutical companies, government, vaccine technology, fear of side effects and perceived immunity against COVID-19. Respondents were more likely to be vaccinated if recommended by their physicians (OR 6.4, 95% CI 2.8–8.3), employers (OR 2.5, 95% CI 1.9–5.8), and family and friends (OR 1.6, 95% CI 1.1–4.5).
Conclusion: We found a suboptimal COVID-19 vaccination rate in a cohort of patients who recovered from severe infection. COVID-19 vaccine information and recommendation by healthcare providers, employers, and family and friends may improve vaccination uptake.

1. Introduction

As of June 1, 2021, there have been more than 3 million confirmed deaths from COVID-19 and 140 million cases globally [1]. The economic impact of COVID-19 infection has been devastating. The United States is one of the countries with the highest burden of COVID-19 infection. The US makes up about 4.25% of the world population and responsible for an estimated 20% of COVID-19 cases and mortality [1]. Now, with the availability of multiple effective and safe vaccines, an end to the pandemic may be feasible through adequate vaccination uptake and coverage [2].

Vaccination and vaccine hesitancy have been well studied in public health in the prevention of infectious diseases especially influenza vaccination [3]. Prior to the availability and approval of COVID-19 vaccines in the US, studies showed a vaccine acceptability rate of between 40% and 70% with the highest level of hesitancy noted in African Americans, people with low level of education and the unemployed [4,5]. The first COVID-19 vaccines were approved for use by the US food and drug administration in December 2020 and as of August 1, 2021, about 58% of US adults have received at least 1 dose of a COVID-19 vaccine [6].

The centers for disease control and prevention (CDC) recommends COVID-19 vaccination for patients who were infected with COVID-19 infection as there is currently no clear evidence on the duration of natural immunity from a previous COVID-19 infection and the role of infection severity on the immune response [7]. Given that a significant proportion of the US population has been

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https://doi.org/10.1016/j.vaccine.2021.10.015
0264-410X/

infected and recovered from COVID-19 vaccine infection, it is important to understand the vaccination behavior and uptake in this unique population.

We surveyed a cohort of patients who recovered from severe SARS-CoV-2 infection to determine the COVID-19 vaccination rate. We also compared the willingness to accept COVID-19 vaccine before and after its availability to assess changes in perception and attitude towards vaccination. We selected this unique population to explore how their experiences with COVID-19 infection may have impacted their vaccination behavior.

2. Methods

2.1. Data collection

Using the electronic health record (EHR) system EPIC software, we identified patients who were mechanically ventilated for severe hypoxemic respiratory failure from SARS-CoV-2 infection and treated in the ICU at Grady Memorial Hospital, Atlanta, Georgia between April 1, 2020, and June 30, 2020. We selected patients who recovered and were subsequently discharged from the hospital during the study period to participate in the study. The survey questionnaire was administered over the phone by trained physicians on the likelihood to accept a 'proven safe and effective' COVID-19 vaccine when available and factors impacting their decisions. These patients were followed up after COVID-19 vaccines have been approved and available for use in the US. We administered another survey between May 10, 2021 and June 5, 2021 to determine their vaccination status and changes in perception towards COVID-19 vaccine. Vaccination status was determined by asking the participants if they had received at least 1 dose of the Pfizer-BioNTech (BNT162b2 mRNA) or Moderna (mRNA-1273 SARS-CoV-2 vaccines and intended to receive the second dose or if they had received the single dose Johnson and Johnson (Ad26. COV2. S) vaccine.

The respondents were also asked to report reasons that guided their decision to receive or decline vaccination. The survey questionnaires (Appendix A) were developed based on previous research on vaccination behavior and factors affecting vaccination acceptance in the US [3,8–10].

Table 1
Sociodemographic and clinical characteristics of patients and likelihood of accepting COVID-19 vaccination.

Variables	Total - N (%)	Likelihood of COVID-19 Vaccination 'Yes' (%) Group A	Likelihood of COVID-19 Vaccination 'No' (%) Group B	Likelihood of COVID-19 Vaccination 'Undecided' (%) Group C
	98 (100)	40 (41)	45 (46)	13 (13)
Sex				
Female	35 (36)	12 (34)	16 (46)	7 (20)
Male	63 (64)	28 (44)	29 (46)	6 (10)
Race				
Non-Hispanic Blacks (NHB)	74 (76)	27 (36)	35 (47)	12 (16)
Non-Hispanic Whites (NHW)	17 (16)	11 (64)	5 (29)	1 (6)
Hispanics	6 (8)	1 (17)	5 (83)	–
Other Race[a]	1	1 (100)	–	–
Age (Median 62 IQR [47.25–73] y				
18–34	10 (10)	3 (30)	6 (60)	1 (10)
35–49	27 (28)	6 (22)	19 (70)	2 (8)
50–74	37 (38)	18 (70)	12 (22)	7 (8)
>75	24 (24)	13 (54)	8 (33)	3 (13)
Health Insurance				
Medicare or Medicaid	41 (42)	17 (41)	19 (46)	5 (12)
Private insurance	38 (39)	15 (39)	17 (45)	6 (16)
Uninsured	19 (19)	8 (42)	9 (47)	2 (11)
Co-morbidities				
Asthma	13 (13)	4 (31)	7 (54)	2 (15)
Coronary artery disease	18 (18)	7 (39)	9 (50)	2 (11)
Cancer	9 (9)	3 (33)	6 (67)	–
Congestive heart failure	21 (21)	7 (33)	11 (52)	3 (14)
Chronic kidney disease 3 and above	23 (23)	8 (35)	12 (52)	3 (13)
Chronic obstructive pulmonary disease	20 (20)	7 (35)	10 (50)	3 (15)
Cerebrovascular accident	17 (17)	6 (35)	10 (59)	1 (6)
Diabetes mellitus	24 (24)	9 (38)	12 (50)	3 (12)
HIV/AIDS	5 (5)	4 (80)	1 (20)	–
Hypertension	54 (55)	21 (39)	28 (52)	5 (9)
Obstructive sleep apnea	14 (14)	4 (29)	8 (57)	2 (14)
No of comorbidities				
No comorbidities	15 (15)	1 (7)	12 (80)	2 (13)
1 co-morbidity	8 (8)	1 (12)	6 (75)	1 (12)
>1 co-morbidity	75 (77)	38 (51)	27 (36)	10 (13)
Body mass index (BMI)				
<30 kg/m^2	57 (58)	20 (35)	28 (49)	9 (16)
≥30 kg/m^2 to <35 kg/m^2	10 (10)	4 (40)	4 (40)	2 (20)
≥35 kg/m^2	31 (32)	16 (52)	13 (42)	2 (6)
Tobacco use				
Never	35 (36)	15 (43)	17 (49)	3 (8)
Previous smoker	42 (43)	17 (40)	19 (45)	6 (14)
Current smoker	21 (21)	8 (38)	9 (43)	4 (19)

Group A - Patients who responded 'Yes' to the survey question, Will you accept a proven safe and effective COVID-19 vaccine when it is available?
Group B - Patients who responded 'No' to the survey question, Will you accept a proven safe and effective COVID-19 vaccine when it is available?
Group C - Patients who responded 'Undecided' to the survey question, Will you accept a proven safe and effective COVID-19 vaccine when it is available?
[a] Other races: Asians, Pacific-islanders, and American natives.

2.2. Statistical analysis

We categorized respondents into 3 groups based on their intention to receive a safe and effective COVID-19 vaccine when available. Patients who responded 'Yes, I will accept proven safe and effective COVID-19 vaccine' were in group A; those who responded 'No' were in group B and those who were 'Undecided' were categorized in group C. We calculated sample descriptive statistics (frequencies and percentages) of socio-demographic characteristics and comorbidities according to participants responses. We determined the association between age and the decision to accept vaccination among the patients that answered 'Yes'. Logistic regression was used to estimate the association (odds ratio) between predictors (covariates) and COVID-19 vaccination acceptance (outcome).

For the follow up survey, we calculated the vaccination rate of the cohort at the time. We also determined the sources of information about COVID-19 vaccination including information and recommendations received by physicians, media, family, friends and employers, and reasons for declining the COVID-19 vaccine based on previously published studies on COVID-19 vaccination behaviour [10]. Lastly, we evaluated the association between ethnicity and age groups and the decision to accept COVID-19 vaccines. Data analysis was performed using R version 3.6.3 (R Foundation) and a two-sided P-value < 0.05 was considered statistically significant. The study was approved by the Morehouse School of Medicine institutional review board and verbal informed consent was obtained from the participants.

3. Results

3.1. Baseline characteristics of the study cohort and intention to receive vaccination before vaccine availability

A total of 98 patients completed the initial survey. Table 1 shows the socio-demographic and clinical characteristics of the patients. The median age was 62 years (IQR, 47.25–73 years) and 67% were males. More males intended to get vaccinated against COVID-19 compared to females (42% vs. 34%). Most of the participants were non-Hispanic Blacks (NHB) (76%) followed by non-Hispanic Whites (16%). The most prevalent comorbidity was hypertension (55%) followed by diabetes mellitus (25%) and 77% of the patients had more than 1 medical co-morbidity. 41% of the patients intended to receive vaccination, 46% responded they would not accept a vaccine against COVID-19 even if it were proven to be safe and effective and 13% of the respondents were undecided.

Among patients with multiple medical co-morbidities, 36% responded 'No' to potentially accepting the vaccine and 51% responded 'Yes' while 93% of patients with no comorbidities showed hesitancy to COVID-19 vaccination. Non-Hispanic Whites (NHW) had the highest vaccination acceptability rate (64%, n = 11/17) followed by NHB (36%, n = 27/74) and Hispanics (17%, n = 1/6).

Major reasons cited by respondents who showed hesitation ('No' and 'Undecided') towards receiving COVID-19 vaccination (n = 58) included fear of side effects from the vaccine (49%), perception that the vaccine will not be effective irrespective of what the research showed (48%), fear that COVID-19 vaccine could make pre-existing medical condition worse (22%) and 42% believed they were already immune against a COVID-19 re-infection (Fig. 1). In some cases, there were significant disparities in the reasons for potentially refusing vaccination. 49% of NHB vs 17% of non-Hispanic whites (NHW) expressed distrust in the vaccine-making pharmaceutical companies as the reason for potentially declining the vaccine. Relative to other ethnicities, 13% of NHB stated they were generally against all vaccines and 15% did not believe COVID-19 was a severe disease despite experiencing severe COVID-19 infection.

3.2. Vaccination status of respondents after availability of COVID-19 vaccine

A total of 93 out of 98 participants completed the follow up survey (Table 2). Three of the patients had died at the time of the follow up survey and we could not get in touch with 2 patients. The

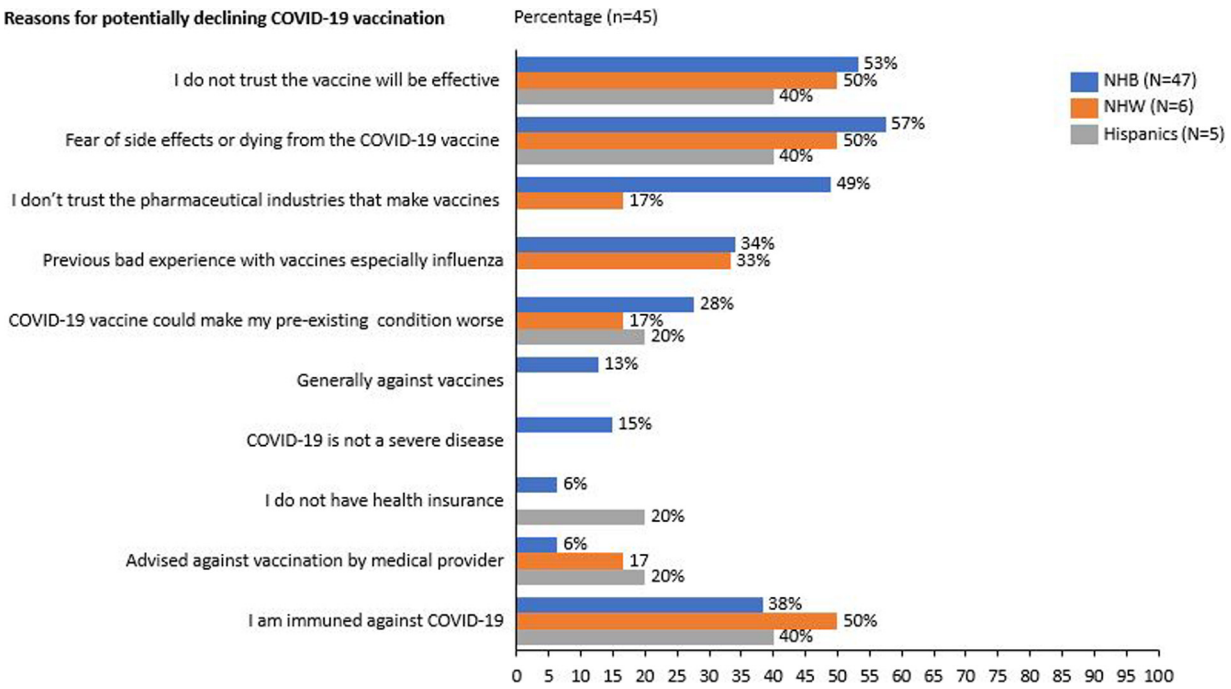

Fig. 1. Reasons for COVID-19 vaccine hesitation among study respondents. N = 58, multiple answers possible. NHB – Non-Hispanic Black, NHW – Non-Hispanic White. Information obtained from survey prior to vaccine availability

Table 2
Characteristics and COVID-19 Vaccination Status of Patients Obtained from the Follow up Survey.

Variables	Total - N (%)	Vaccinated – N (%)		Vaccination in Group A (N = 38)		Vaccination in Group B (N = 42)		Vaccination in Group C (N = 13)	
		Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)
	93 (100)	41 (44)	52 (56)	23 (61)	15 (39)	16 (38)	26 (62)	2 (15)	11 (85)
Sex									
Female	31 (33)	17 (55)	14 (45)	9 (56)	7 (44)	7 (54)	6 (46)	1 (50)	1 (50)
Male	62 (67)	24 (39)	38 (61)	14 (64)	8 (36)	9 (31)	20 (69)	1 (9)	10 (91)
Race									
Non-Hispanic Blacks (NHB)	71 (76)	28 (39)	43 (61)	13 (52)	12 (48)	14 (40)	21 (60)	1 (9)	10 (91)
Non-Hispanic Whites (NHW)	15 (16)	10 (67)	5 (33)	9 (90)	1 (10)	0 (0)	3 (100)	1 (50)	1 (50)
Hispanics	6 (6)	2 (33)	4 (67)	0	2 (100)	2 (50)	2 (50)	0	0
Other Race[a]	1 (11)	1 (100)	0	1 (100)	0	0	0	0	0
Age (Median 62 IQR [47.25–73]) y									
18–34	10 (11)	0	10 (100)	0 (0)	5 (100)	0 (0)	3 (100)	0 (0)	2 (100)
35–49	27 (29)	5 (19)	22 (81)	3 (30)	7 (70)	2 (20)	8 (80)	0 (0)	7 (100)
50–74	35 (38)	20 (57)	15 (43)	11 (85)	2 (15)	8 (40)	12 (60)	1 (50)	1 (50)
>75	21 (23)	16 (76)	5 (24)	9 (90)	1 (10)	6 (67)	3 (33)	1 (50)	1 (50)
Health Insurance									
Medicare or Medicaid	40 (43)	15 (38)	25 (63)	6 (40)	9 (60)	8 (36)	14 (64)	1 (33)	2 (67)
Private insurance	35 (38)	18 (51)	17 (49)	12 (75)	4 (25)	6 (40)	9 (60)	0 (0)	4 (100)
Uninsured	18 (19)	8 (44)	10 (56)	5 (71)	2 (29)	2 (40)	3 (60)	1 (17)	5 (83)
Co-morbidities									
Asthma	13 (14)	3 (23)	10 (77)	2 (22)	7 (78)	1 (33)	2 (67)	0 (0)	1 (100)
Coronary artery disease	18 (19)	7 (39)	11 (61)	5 (45)	6 (55)	2 (33)	4 (67)	0 (0)	3 (100)
Cancer	9 (10)	5 (56)	4 (44)	3 (50)	3 (50)	2 (67)	1 (33)	0 (0)	0 (0)
Congestive heart failure	21 (23)	10 (48)	11 (52)	7 (47)	8 (53)	4 (67)	2 (33)	0 (0)	1 (100)
Chronic kidney disease 3 and above	22 (24)	13 (59)	9 (41)	9 (64)	5 (36)	3 (43)	4 (57)	1 (100)	0 (0)
Chronic obstructive pulmonary disease	20 (22)	13 (65)	7 (35)	8 (62)	5 (38)	5 (83)	1 (17)	0 (0)	1 (100)
Cerebrovascular accident	17 (18)	9 (53)	8 (47)	7 (64)	4 (36)	2 (33)	4 (67)	0 (0)	0 (0)
Diabetes mellitus	21 (23)	14 (67)	8 (38)	10 (63)	6 (38)	4 (80)	1 (20)	0 (0)	1 (100)
HIV/AIDS	5 (5)	4 (80)	1 (20)	3 (100)	0 (0)	1 (50)	1 (50)	1 (100)	0 (0)
Hypertension	52 (56)	29 (56)	23 (44)	19 (61)	12 (39)	9 (64)	5 (36)	1 (14)	6 (86)
Obstructive sleep apnea	14 (15)	9 (64)	5 (36)	7 (70)	3 (30)	1 (50)	1 (50)	1 (50)	1 (50)
No of comorbidities									
No comorbidities	15 (16)	3 (20)	12 (80)	2 (20)	8 (80)	1 (25)	3 (75)	0 (0)	1 (100)
1 co-morbidity	8 (9)	5 (63)	3 (38)	2 (67)	1 (33)	2 (50)	2 (50)	1 (100)	0 (0)
>1 co-morbidity	70 (75)	33 (47)	37 (53)	19 (76)	6 (24)	13 (38)	21 (62)	1 (9)	10 (91)
Body mass index (BMI)									
<30 kg/m^2	55 (59)	22 (40)	33 (60)	12 (55)	10 (45)	9 (36)	16 (64)	1 (13)	7 (88)
≥30 kg/m^2 to <35 kg/m^2	10 (11)	2 (20)	8 (80)	1 (20)	4 (80)	1 (25)	3 (75)	0 (0)	1 (100)
≥35 kg/m^2	28 (30)	17 (61)	11 (39)	10 (91)	1 (9)	6 (46)	7 (54)	1 (25)	3 (75)
Tobacco use									
Never	33 (36)	12 (36)	21 (64)	5 (42)	7 (58)	6 (40)	9 (60)	1 (17)	5 (83)
Previous smoker	40 (43)	14 (35)	26 (65)	9 (56)	7 (44)	4 (22)	14 (78)	1 (17)	5 (83)
Current smoker	20 (21)	15 (75)	5 (25)	9 (90)	1 (10)	6 (67)	3 (33)	0 (0)	1 (100)

Group A - Patients who responded 'Yes' to the survey question, Will you accept a proven safe and effective COVID-19 vaccine when it is available?
Group B - Patients who responded 'No' to the survey question, Will you accept a proven safe and effective COVID-19 vaccine when it is available?
Group C - Patients who responded 'Undecided' to the survey question, Will you accept a proven safe and effective COVID-19 vaccine when it is available?
[a] Other races: Asians, Pacific-islanders, and American natives.

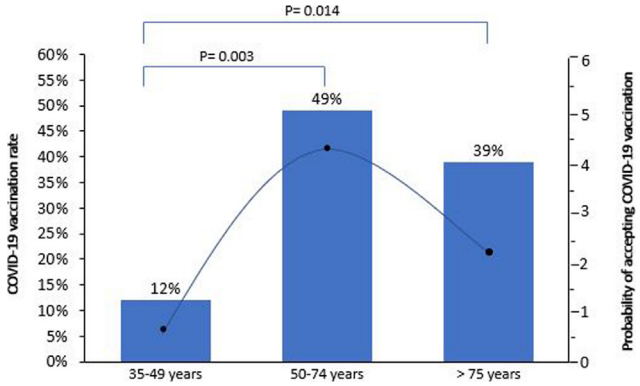

Fig. 2. Vaccination rate in percentages by Age group shown by histogram and odds ratios for probability of vaccination depicted as spline graph. The youngest age group (18–34 years) serves as reference group for calculating odds ratios and p-values in comparison to other age groups.

total vaccination rate of the cohort was 44%. The vaccination rates in groups A, B and C were 61%, 38% and 15% respectively. African Americans and Hispanics had the lowest vaccination rates (39% and 33% respectively) vs. 67% in Whites. Patients ≥ 75 years of age had the highest vaccination rate of 76%. There was significant association between age and vaccination rate. Compared to the reference age group (15–34 years), 49% of patients in the 50-74y age group (OR 4.2, 95% CI 1.36–5.22) and 39% of patients ≥ 75 years (OR 2.0, 95% 1.11–4.24) were more likely to receive COVID-19 vaccine (Fig. 2).

Major reasons provided by respondents for not accepting COVID-19 vaccine were lack of trust in the effectiveness of the vaccine, pharmaceutical companies, government, vaccine technology, fear of side effects and perceived immunity against COVID-19 re-infection (Fig. 3). Notably, 35% of African Americans mentioned lack of access to COVID-19 vaccines as a challenge to vaccination. Similar reasons were shared across the different age groups. However, patients between 18 and 49 years were more hesitant to receive COVID-19 vaccine because they felt the vaccine was developed too quickly, wariness and distrust in the vaccine technology

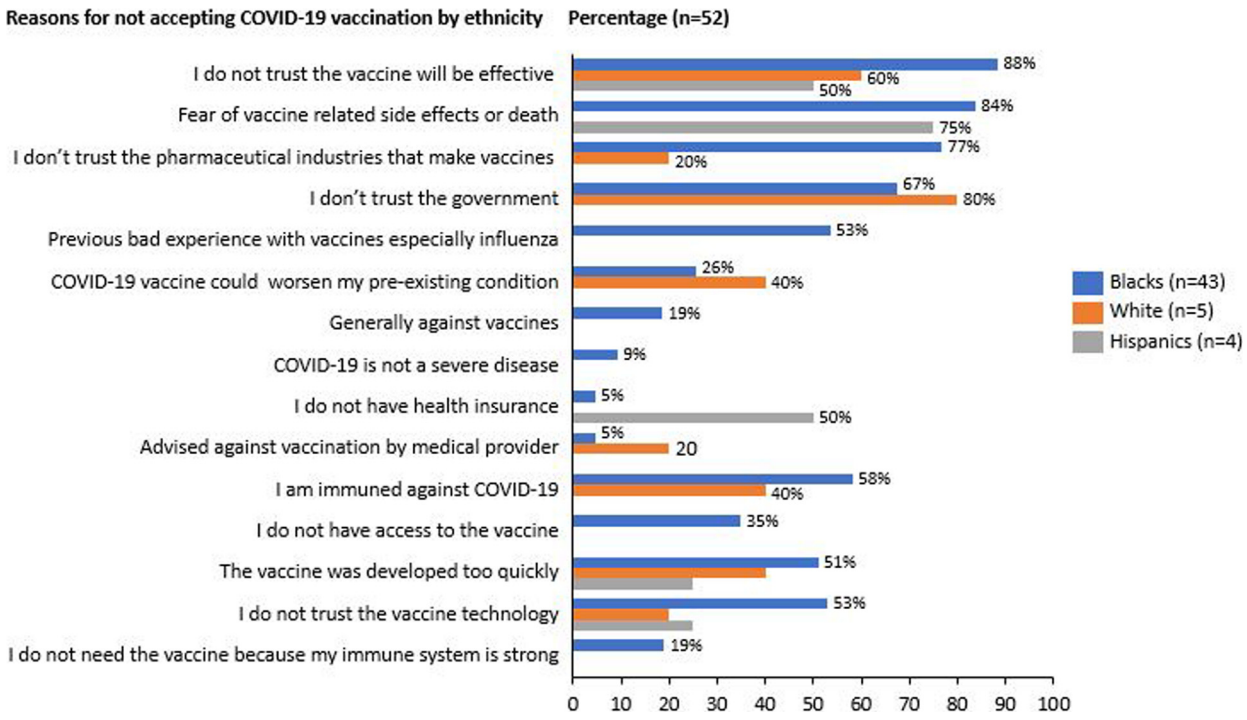

Fig. 3. Reasons for declining vaccination among study respondents. N = 52, multiple answers possible. NHB – Non-Hispanic Black, NHW – Non-Hispanic White. Information obtained from follow up survey after vaccine availability.

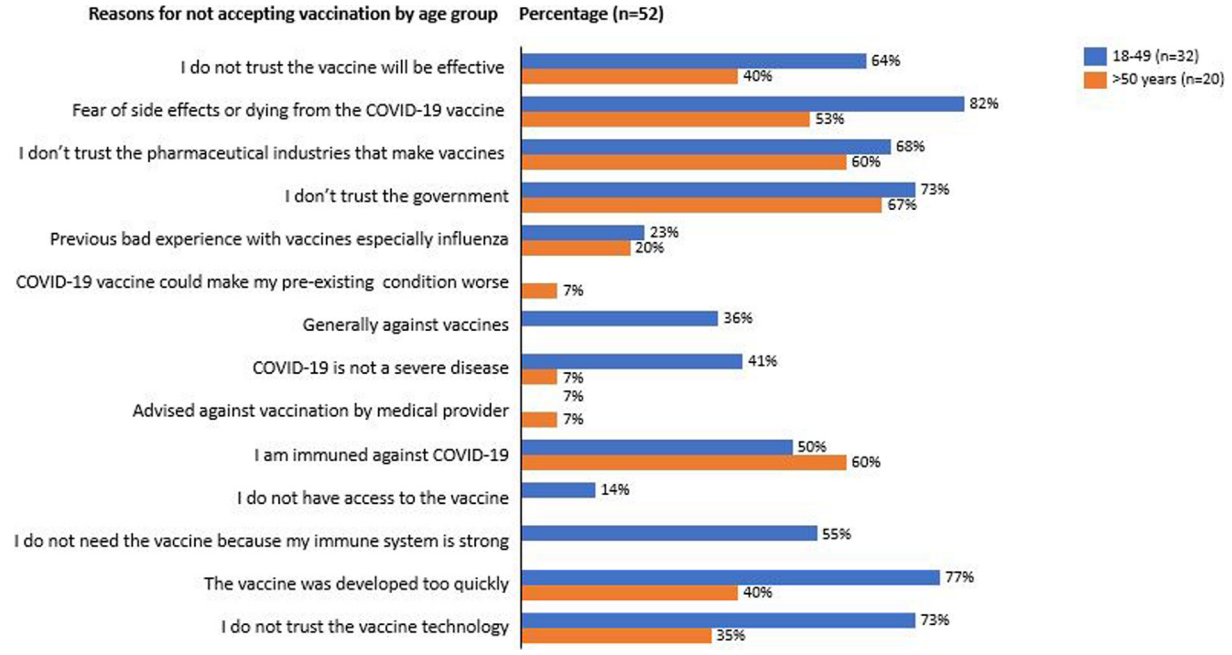

Fig. 4. Reasons for declining COVID-19 vaccine among study respondents categorized by age groups. N = 52, multiple answers possible. NHB – Non-Hispanic Black, NHW – Non-Hispanic White. Information obtained from follow up survey after vaccine availability.

and a perception of strong immunity against COVID-19 infection (Fig. 4).

Among respondents who were initially hesitant to receive COVID-19 vaccination prior to availability of the vaccine (n = 55), 33% changed their minds and received the vaccine. Direct recommendation by their doctors and employers, encouragement from family and friends and the desire to protect their family and others motivated them to receive the vaccine (Fig. 5). The respondents in the hesitant group who did not change their minds declined COVID-19 vaccination for the same reasons that they were initially resistant prior to availability of the vaccine (Fig. 1).

On multivariate logistic regression, respondents were more likely to be vaccinated if recommended by their physicians (OR 6.4, 95% CI 2.8–8.3), employers (OR 2.5, 95% CI 1.9–5.8), and family and friends (OR 1.6, 95% CI 1.1–4.5) and family (There was no statistically significant association between COVID-19 vaccination

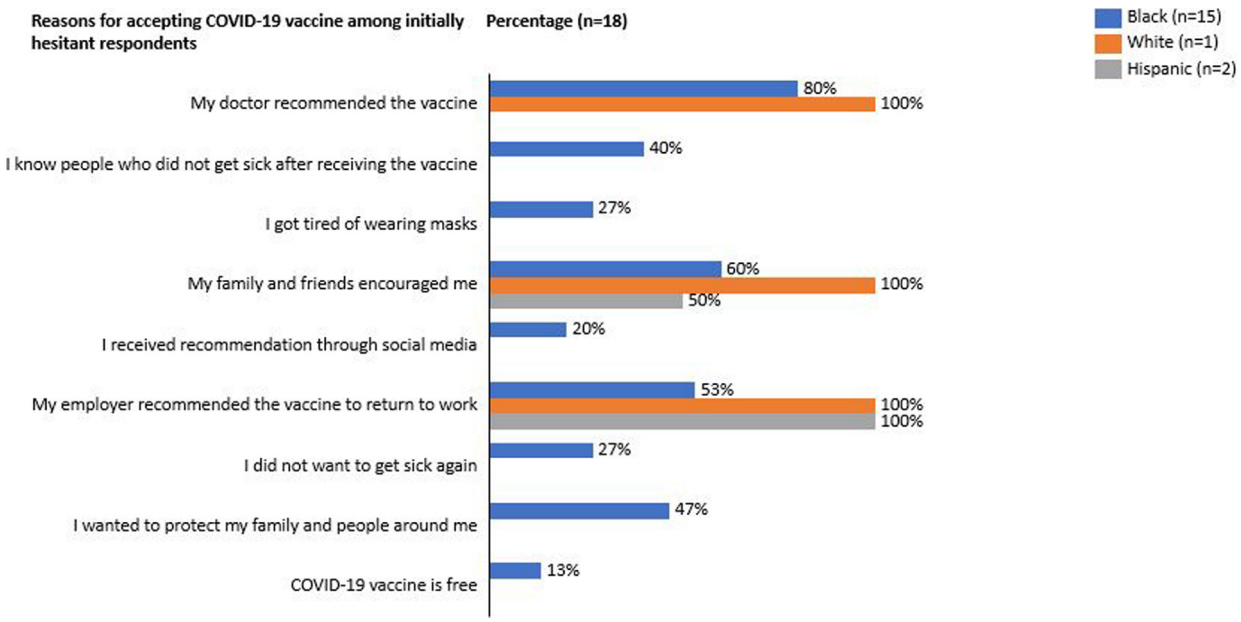

Fig. 5. Reasons for vaccine acceptance among initially hesitant respondents categorized by race . N = 18. Multiple answers possible. NHB – Non-Hispanic Black, NHW – Non-Hispanic White. Iinformation obtained from follow up survey after vaccine availability.

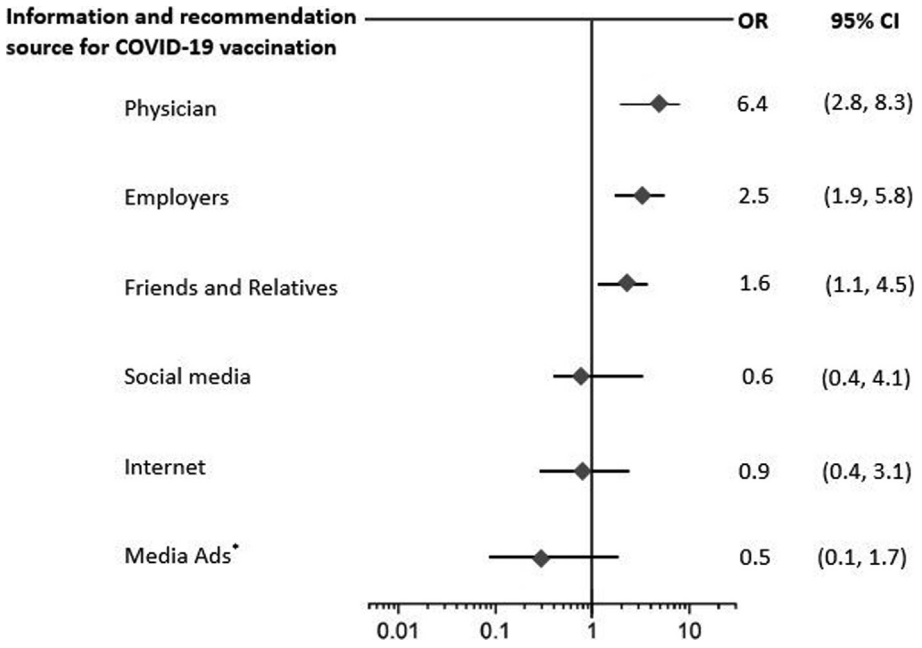

Fig. 6. Predictors of COVID-19 vaccination acceptance according to the different sources utilized by patients to obtain information about their health and vaccines. Odds ratios are adjusted for age, sex, and ethnicity, *Television, radio, and newspapers.

acceptability and obtaining information or recommendation for COVID-19 vaccine through the media and the internet (Fig. 6).

4. Discussion

In this cohort of patients with severe COVID-19 infection who subsequently recovered and were discharged from the hospital, the COVID-19 vaccination rate was 44%. This is similar to the proportion of the cohort (41%) who expressed that they would likely receive the vaccine in a survey during the developmental stages of the vaccine. As of August 1, 2021, about 58% of the U.S. population has received at least one dose of a COVID-19 vaccine and 42% is fully vaccinated [11]. Currently, the vaccination rate in previously infected individuals is not reported, therefore, our study provides novel findings on vaccination rates in previously infected patients with severe COVID-19 infection. Considering that our study population had severe COVID-19 infection, we expected higher COVID-19 vaccine acceptability rates to reduce the risk of re-infection.

We found significant differences in the vaccination rates across ethnicities and age groups. Though African Americans and Hispanics have disproportionately higher rates of hospitalizations and deaths from COVID-19 infection, they had the lowest vaccination

rates compared to Whites. This also mirrors the racial disparities in current vaccination status as African Americans and Hispanics are getting vaccinated at disproportionately low rates compared to Whites. As of August 1, 2021, the CDC reported a national COVID-19 vaccination rate of 58% in people with known race/ethnicity out of which 59% were White, 10% were Black, and 16% were Hispanic [6]. In our study, the major concerns for showing hesitation towards COVID-19 vaccination were similar across the different racial groups and did not appear to have changed before and after availability of COVID-19 vaccines.

Respondents were still unwilling to be vaccinated due to fear of side effects, perception that the vaccine may not be effective, distrust of the government and pharmaceutical companies. Additionally, respondents aged 18–49 years were particularly hesitant because the vaccine was developed too quickly coupled with distrust in the vaccine technology and the perception of strong immune system to fight COVID-19 infection. The skepticism in the vaccine pharmaceutical industry was more prominent in African Americans which stems from historical experiences of racial discrimination and abuse in healthcare and lack of trust in the scientific community to act in their best interests [12,13].

It is concerning that about 35% of African Americans in this study could not get the vaccine due to lack of access. Studies show that Black and Hispanic people in the United States are less likely than Whites to have reliable internet access enough to make online appointments and access to dependable transportation to receive vaccines [14]. Also, a lack of access to information about vaccines through trusted providers leads to uncertainty and an unwillingness to get vaccinated [15]. Racial inequities in access to essential healthcare treatment have also been reported in the use of pre-exposure prophylaxis (PrEP) for human immunodeficiency virus (HIV) infection between white and black men having sex with men [16]. Ensuring community health centers that primarily serve minority populations have adequate COVID-19 vaccines may improve access and vaccine uptake.

Older age (>50 years) was associated with a higher vaccination rate which is consistent with previous studies that showed a relatively higher influenza vaccination rate in this age group. We believe that this population is more willing to accept COVID-19 vaccine because they are in the high-risk group for severe COVID-19 infection and adverse outcomes. Also, they likely already receive periodic vaccinations against other infections such as influenza and pneumonia and are familiar with the benefits of vaccination [3].

Interestingly, a significant proportion of the cohort believed they were already immune against COVID-19 infection due to their previous infection. Currently, there is limited evidence to conclude that previously infected individuals have long-term natural immunity against re-infection. Though, a recent study reported detection of anti-SARS-CoV-2 IgG antibodies with confirmed neutralization activity for up to 6 months post infection, there have been cases of re-infection within 2 months of the index infection [7,17,18]. More research is necessary to better understand the extent of immunity from previous COVID-19 infection and previously infected individuals need to be educated that they still require vaccination to reduce the likelihood of another severe COVID-19 infection.

We found that 33% of initially hesitant respondents received the COVID-19 vaccines when they became available. Recommendation by physicians and employers appeared to have played significant roles in changing their mindset. Other reasons included encouragement from family and friends, the desire to protect others from getting sick and the assurance that the vaccine was safe because they knew people who did not get sick after receiving the vaccine. After adjusting for age, race and co-morbidities, respondents were significantly more likely to be vaccinated if they received the vaccine information and recommendation from their physicians, employers, family, and friends. Our findings are consistent with a study by Razai *et al*., which evaluated the 5c model to highlight the effect of 'communications' (sources of information) and 'context' (sociodemographic characteristics) on COVID-19 vaccine hesitancy [10]. Healthcare provider recommendation has been shown to significantly improve the uptake of vaccines especially in patients with high-risk conditions [9]. Consistent COVID-19 vaccine recommendation by medical providers to eligible patients may positively impact vaccination behavior and improve uptake. Additionally, we recommend that employers participate actively in vaccination campaigns and continue to encourage their employees to get vaccinated.

To effectively reduce COVID-19 transmission through herd immunity, a COVID-19 vaccine uptake of 70% or more in the population may be necessary [19]. Furthermore, unvaccinated individuals are at risk of severe infection and death especially from the new variants of COVID-19 that have been shown to be more transmissible and deadly. Our study therefore shows that public health efforts need to be intensified to promote COVID-19 vaccination uptake and ensure optimal coverage particularly among patients who recovered from severe COVID-19 infection.

Our study is not without limitations. We recognize that the relatively small sample size is a limitation, however, the study cohort is a subset of a unique population of patients who experienced severe COVID-19 infection and we believe it is important to understand their intent to be vaccinated against COVID-19 and how this has changed over time. We did not ask the participants if their friends or close relatives had COVID-19 infection which could have impacted their decision on COVID-19 vaccination. Also, recruitment of the participants post-discharge from the hospital and while in the community may subject the participants to unique and contextual community elements that could not be measured in this study and may have impacted vaccination behavior. Lastly, the respondents were predominantly African Americans which may impact its generalizability.

In conclusion, a significant proportion of our patient cohort that recovered from severe infection had not received COVID-19 vaccination. The vaccination rates were significantly low among African Americans and Hispanics respondents which is particularly concerning because they are overrepresented among the number of COVID-19 hospitalizations and deaths in the US. One-third of the study cohort who were initially hesitant changed their minds and received the COVID-19 vaccine because of recommendations from their physicians, employers, and family and friends. Addressing concerns and correcting misconceptions highlighted in this study may improve vaccine uptake.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.vaccine.2021.10.015.

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