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Individual-level factors associated with COVID-19 vaccine acceptance among U.S. patients with cancer

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ABSTRACT

Introduction: Vaccine hesitancy in the wake of the COVID-19 pandemic is a major public health concern in the US. Cancer patients are especially vulnerable to adverse COVID-19 outcomes and require targeted prevention efforts against COVID-19.
Methods: We used longitudinal survey data from patients seen at Moffitt Cancer Center to identify attitudes, beliefs, and sociodemographic factors associated with COVID-19 vaccination acceptance among cancer patients. Patients with confirmed invasive cancer diagnosis through Cancer Registry data were asked about vaccine acceptance through the question "Now that a COVID-19 vaccine is available, are you likely to get it?" and dichotomized into high accepters (already received it, would get it when available) and low accepters (waiting for a doctor to recommend it, waiting until more people received it, not likely to get it).
Results: Most patients (86.8% of 5,814) were high accepters of the COVID-19 vaccine. High accepters had more confidence in the effectiveness and safety of the vaccine than low accepters. Multivariable logistic regression showed older individuals (70–89 vs.18–49: OR:2.57, 95% CI:1.33–4.86), those with greater perceived severity of COVID-19 infection (very serious vs. not at all serious: OR:2.55, 95% CI:1.76–3.70), practicing more risk mitigation behaviors (per one standard deviation OR:1.75, 95% CI:1.57–1.95), and history of receiving the flu shot versus not (OR:6.56, 95% CI:5.25–8.20) had higher odds of vaccine acceptance. Individuals living with more than one other person (vs. alone: OR: 0.53, 95% CI: 0.35, 0.79) and those who were more socioeconomically disadvantaged (per 10 percentile points: OR: 0.89, 95 %CI: 0.85, 0.93) had lower odds of reporting vaccine acceptance.
Conclusion: Most patients with cancer have or would receive the COVID-19 vaccine. Those who are less likely to accept the vaccine have more concerns regarding effectiveness and side effects, are younger, more socioeconomically disadvantaged, and have lower perceptions of COVID-19 severity.

1. Introduction

Vaccine hesitancy is an ongoing public health issue, particularly in the U.S., [1–7] and is an intricate behavioral concept that is due to a combination of physical (e.g., health behaviors), contextual (e.g., access to vaccines), and sociodemographic (e.g., age) factors acting on physiological determinants of decision-making (e.g., beliefs and attitudes) that influence vaccine uptake. [7] Several physiological determinants can influence behavior and attitudes towards influenza vaccine uptake, including perceptions of infection risk, views of societal benefits, attitudes towards effectiveness of the vaccine, past vaccine behaviors or experiences, and vaccine knowledge. [7].

For COVID-19, there is a wide range of vaccine acceptance across the U.S. [8,9] Studies in the general population have observed that older age, male sex, and having an influenza vaccine increased acceptance of COVID-19 vaccines. [10,11] Other factors positively associated with COVID-19 vaccine acceptance included higher income, higher education, stronger perceived risk or sever-

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ity of a SARS-CoV-2 infection, and greater fear of COVID-19 in general. [10–15] Hesitancy toward COVID-19 vaccination was also associated with fear of potential vaccine side effects and concern about the efficacy of the vaccine. [10,12,13,16].

Individuals with cancer are more susceptible to SARS-CoV-2 infection and associated outcomes, and thus, are an important population to target for COVID-19 vaccine acceptance. [17,18] Nonetheless, patients with cancer may fear how the COVID-19 vaccine may impact their cancer treatment and be less incline to get vaccinated. [19] However, few studies of COVID-19 vaccine acceptance have focused on patients with cancer and even less have evaluated hesitancy toward the COVID-19 vaccine in this population. [19–25] Therefore, we conducted a study among patients at a large comprehensive cancer center with invasive cancer to identify sociodemographic factors, behaviors, and attitudes that may influence acceptance of the COVID-19 vaccination.

2. Material and methods

2.1. Study population and ethical statement

We recruited patients from Moffitt Cancer Center seen on or after January 1, 2015, who had a valid email address, a vital status of alive as of the date the first survey was emailed, and were 18–89 years of age. All patients regardless of cancer diagnosis were emailed a baseline survey between June 2020 and February 2021 with 90% of surveys completed in December 2020 (T0, n = 10,820). Follow-up surveys were sent to patients who completed the baseline survey from February to April 2021 (T1, 94% completed in March 2021, n = 7,015) and April to July 2021 (T2, 94% completed in May 2021, n = 6,124). Response rates for the baseline survey was 21.0% and among those who completed the baseline survey, we had a 64.8% response rate for the first follow up survey, and 56.6% for the second follow up survey. This study was restricted to participants who completed the first follow up survey with a confirmed invasive cancer diagnosis (n = 5,814). This study was approved by Advarra Inc. institutional review board with a waiver of documented informed consent (MCC 20629, Pro00043372).

2.2. COVID-19 vaccine acceptance

Follow-up surveys were administered after the US Food and Drug Administration granted emergency use authorization for two COVID-19 vaccines in December 2020. [26,27] We asked participants on each follow-up, "Now that a COVID-19 vaccine is available, are you likely to get it?" with responses of 1) Yes, I have already received it, 2) Yes, as soon as it's available to me, 3) I'll wait until my doctor recommends it, 4) I'll wait until enough people have received it to know if it works, and 5) I am not likely to get any COVID-19 vaccine. We consider the first two responses as "high accepters" and the other responses as "low accepters" of the vaccine. Participants who did not answer this question (n = 141) were removed from the analysis.

We assessed discordance between acceptance of the vaccine at T1 and T2. Participants who were low accepters at T1 and high accepters at T2 were considered to have positive discordance. Those who reported high acceptance during at T1 and low acceptance at T2 were considered to have negative discordance.

2.3. Predictors

Electronic medical records were used to assess age at T0 (18–49, 50–59, 60–69, 70–89), sex (male, female), marital status (married/life partner], not married [divorced, widowed, single]), and nine-digit residence zip code. Socioeconomic status was assessed using the National Area Deprivation Index, which uses zip code to assign census block group level of income, education, employment, and housing quality, with higher percentile scores indicating more disadvantaged areas. [28,29] Cancer type (hematologic, solid) and age at most recent cancer diagnosis (continuous) were extracted from Cancer Registry.

Additional predictors were self-reported at baseline including race (white, non-white), ethnicity (non-Hispanic, Hispanic), living arrangement (alone, living with one other person, living with more than one other person), employment status (employed, retired, unemployed), annual household income, health insurance status (insured, not insured), healthcare worker status (never, past, current), and smoking status (never smoked, past smoker, current smoker).

We asked participants at baseline if they ever had a COVID-19 test and if so, whether the test was positive to determine prior COVID-19 positivity or negative/never tested. We asked participants about perceived risk of contracting COVID-19 on a scale of 1 (very unlikely) to 5 (very likely), and severity should they get infected (not at all serious, somewhat serious, very serious). We assessed perceived changes in daily life due the COVID-19 pandemic on a scale from 1 (not at all) to 5 (a lot).

Participants also self-reported their frequency of risk or risk mitigation behaviors (i.e., leaving their house for errands, having physical contact with others outside their home, attending social gatherings, using a mask in public places, and using hand sanitizer in public places) from 1 (never) to 5 (very often). [30,31]After appropriate reverse scoring, responses were summed to calculate a total risk mitigation score (ranging from 5 to 25) with higher scores indicating more risk mitigation behaviors, similar to previously published behavior scores. [32] Participants were also asked if they have received a flu shot in 2020–2021 on T1 survey, by which time the flu 2020–2021 season had peaked. [33] Responses were 1) Yes, I already received it, 2) Yes, I plan to get it, 3) Unsure, and 4) No.

2.4. Attitudes and beliefs

We asked participants at T1 about motivation and attitudes towards COVID-19 vaccination, including "Are you confident that the COVID-19 vaccine(s) are effective and safe?" on a Likert scale from 1 (extremely confident) to 5 (not confident at all). Similarly, participants selected potential concerns about the COVID-19 vaccines from the following: overall effectiveness, getting infected with COVID-19 from the vaccine, not being able to afford it, safety or side effects, it was rushed to the market too soon, it will take too long to become available, it may have interacted with my medications, I won't trust any COVID-19 vaccine, COVID-19 isn't a serious illness, I'm not worried about getting COVID-19, I had no concerns about a COVID-19 vaccine, or a write in option to specify other concerns.

Participants reported COVID-19 specific fears on a scale from 1 (strongly disagree) to 5 (strongly agree), including: I feel anxious about getting COVID-19, I worry about possibly infecting others, I am concerned about a family member or close friend getting or dying from COVID-19, I worry about the possibility of dying from COVID-19, I fear how the COVID-19 pandemic will impact my cancer care, recovery or survivorship, I am concerned that cancer puts me at greater risk for being infected or dying from COVID-19, I feel I have no control over how COVID-19 will impact my life, I know where to get accurate COVID-19 information that is specific to me as a cancer patient or survivor.

2.5. Statistical analysis

We conducted descriptive analyses using Chi-square tests to compare attitudes and beliefs regarding COVID-19 vaccination

Table 1
Characteristics of Patients with an Invasive Cancer Diagnosis in the U.S. by COVID-19 Vaccine Uptake and Acceptance Status (n = 5,814; June 2020 – April 2021).

	Already Received It	As Soon As It Is Available	Wait Until Doctor Recommends	Wait Until Enough People Receive It	Not Likely To Get It
n (%)	4440 (76.4)	604 (10.4)	195 (3.4)	290 (5.0)	285 (4.9)
Age Quartiles, n (%)					
18–49	320 (53.4)	119 (19.9)	42 (7.0)	57 (9.5)	61 (10.2)
50–59	520 (56.0)	184 (19.8)	58 (6.3)	92 (9.9)	74 (8.0)
60–69	1448 (77.6)	184 (9.9)	56 (3.0)	88 (4.7)	91 (4.9)
70–89	2152 (88.9)	117 (4.8)	39 (1.6)	53 (2.2)	59 (2.4)
Sex, n (%)					
Male	1920 (80.5)	209 (8.8)	76 (3.2)	88 (3.7)	93 (3.9)
Female	2520 (73.5)	395 (11.5)	119 (3.5)	202 (5.9)	192 (5.6)
Race, n (%)					
White	4229 (77.4)	538 (9.8)	172 (3.2)	263 (4.8)	264 (4.8)
Non-White	211 (60.6)	66 (19.0)	23 (6.6)	27 (7.8)	21 (6.0)
Ethnicity, n (%)					
Non-Hispanic	4178 (76.9)	553 (10.2)	171 (3.2)	269 (5.0)	261 (4.8)
Hispanic	262 (68.6)	51 (13.4)	24 (6.3)	21 (5.5)	24 (6.3)
Marital Status, n (%)					
Married	3432 (77.7)	442 (10.0)	147 (3.3)	198 (4.5)	197 (4.5)
Not married	1008 (72.1)	162 (11.6)	48 (3.4)	92 (6.6)	88 (6.3)
Living Arrangement, n (%)					
Alone	729 (77.6)	89 (9.5)	26 (2.8)	47 (5.0)	48 (5.1)
Living with one other person	2954 (81.1)	318 (8.7)	96 (2.6)	128 (3.5)	147 (4.0)
Living with more than one other person	757 (61.4)	197 (16.0)	73 (5.9)	115 (9.3)	90 (7.3)
Employment Status, n (%)					
Full-Time	803 (62.6)	215 (16.8)	60 (4.7)	113 (8.8)	92 (7.2)
Part-Time	301 (68.6)	58 (13.2)	16 (3.6)	31 (7.1)	33 (7.5)
Retired	2877 (85.9)	217 (6.5)	65 (1.9)	95 (2.8)	96 (2.9)
Unemployed	459 (61.9)	114 (15.4)	54 (7.3)	51 (6.9)	64 (8.6)
Income, n (%)					
≤$19,999	216 (58.2)	64 (17.3)	27 (7.3)	35 (9.4)	29 (7.8)
$20,000-$39,999	514 (73.9)	57 (8.2)	30 (4.3)	37 (5.3)	58 (8.3)
$40,000-$59,999	677 (75.9)	83 (9.3)	31 (3.5)	47 (5.3)	54 (6.1)
≥$60,000	2395 (79.4)	317 (10.5)	78 (2.6)	123 (4.1)	105 (3.5)
Unknown	638 (76.2)	83 (9.9)	29 (3.5)	48 (5.7)	39 (4.7)
Insurance Status, n (%)					
Insured	4336 (77.0)	570 (10.1)	186 (3.3)	274 (4.9)	267 (4.7)
Not Insured	104 (57.5)	34 (18.8)	9 (5.0)	16 (8.8)	18 (9.9)
Healthcare Worker, n (%)					
Never	4045 (76.0)	567 (10.7)	187 (3.5)	262 (4.9)	265 (5.0)
Past	270 (81.1)	31 (9.3)	6 (1.8)	14 (4.2)	12 (3.6)
Current	125 (80.7)	6 (3.9)	2 (1.3)	14 (9.0)	8 (5.2)
Received Flu Shot for 2020–2021, n (%)					
No	545 (48.5)	148 (13.2)	70 (6.2)	137 (12.2)	224 (19.9)
Yes, got it	3449 (85.0)	361 (8.9)	88 (2.2)	111 (2.7)	47 (1.2)
Yes, plan to get it	269 (76.6)	54 (15.4)	13 (3.7)	11 (3.1)	4 (1.1)
Not sure	177 (62.5)	41 (14.5)	24 (8.5)	31 (11.0)	10 (3.5)
Smoking Status, n (%)					
Never	2425 (74.3)	361 (11.1)	122 (3.7)	190 (5.8)	167 (5.1)
Past	1904 (80.6)	211 (8.9)	63 (2.7)	90 (3.8)	93 (3.9)
Current	111 (59.0)	32 (17.0)	10 (5.3)	10 (5.3)	25 (13.3)
COVID-19 Positivity, n (%)					
Tested Positive	100 (59.9)	26 (15.6)	6 (3.6)	10 (6.0)	25 (15.0)
Never Tested/Tested Negative	4340 (76.9)	578 (10.2)	189 (3.4)	280 (5.0)	260 (4.6)
Risk Perception of Contracting COVID-19, n (%)					
Very unlikely to get COVID-19	817 (75.5)	95 (8.8)	38 (3.5)	57 (5.3)	75 (6.9)
Somewhat unlikely to get COVID-19	1278 (80.2)	145 (9.1)	49 (3.1)	61 (3.8)	60 (3.8)
Neither unlikely or likely to get COVID-19	1387 (76.0)	204 (11.2)	59 (3.2)	90 (4.9)	84 (4.6)
Somewhat likely to get COVID-19	643 (76.4)	92 (10.9)	30 (3.6)	56 (6.7)	21 (2.5)
Very likely to get COVID-19	112 (73.7)	14 (9.2)	7 (4.6)	8 (5.3)	11 (7.2)
N/A (had COVID-19) or Unknown	203 (63.2)	54 (16.8)	12 (3.7)	18 (5.6)	34 (10.6)
Severity of COVID-19, n (%)					
Not at all serious	154 (43.6)	49 (13.9)	19 (5.4)	52 (14.7)	79 (22.4)
Somewhat serious	1571 (74.5)	246 (11.7)	68 (3.2)	119 (5.6)	105 (5.0)
Very serious	2511 (82.9)	254 (8.4)	96 (3.2)	100 (3.3)	67 (2.2)
N/A (had COVID-19) or Unknown	204 (63.0)	55 (17.0)	12 (3.7)	19 (5.9)	34 (10.5)
Daily life change due to COVID-19, n (%)					
Not at all	40 (49.4)	14 (17.3)	8 (9.9)	3 (3.7)	16 (19.8)
A little	328 (63.6)	64 (12.4)	22 (4.3)	49 (9.5)	53 (10.3)
Somewhat	722 (72.9)	103 (10.4)	39 (3.9)	64 (6.5)	63 (6.4)
A moderate amount	1325 (77.1)	164 (9.5)	56 (3.3)	86 (5.0)	88 (5.1)
A lot	2025 (80.8)	259 (10.3)	70 (2.8)	88 (3.5)	65 (2.6)

(*continued on next page*)

Table 1 (*continued*)

	Already Received It	As Soon As It Is Available	Wait Until Doctor Recommends	Wait Until Enough People Receive It	Not Likely To Get It
Cancer Type, n (%)					
Hematologic	710 (80.8)	76 (8.7)	38 (4.3)	28 (3.2)	27 (3.1)
Solid	3730 (75.6)	528 (10.7)	157 (3.2)	262 (5.3)	258 (5.2)
Age at Most Recent Cancer Diagnosis, mean (sd)	61.4 (11.2)	53.4 (12.3)	53.9 (12.4)	52.8 (12.2)	54.0 (13.5)
National ADI, mean (sd)	41.4 (22.5)	43.1 (22.6)	47.3 (22.5)	48.8 (22.5)	50.4 (23.1)
Risk mitigation behaviors [a], mean (sd)	20.2 (2.3)	19.9 (2.5)	19.5 (3.0)	18.4 (3.2)	16.9 (4.1)

Abbreviations: ADI: Area Deprivation Index, SD: Standard Deviation.
Percentages may not add to 100% due to rounding.
a Risk mitigation behaviors include leaving their house for errands, having physical contact with others outside their home, attending social gatherings, using a mask in public places, and using hand sanitizer in public places ranging from 5 to 25.

and COVID-19 specific fears among high and low accepters of COVID-19 vaccination. We used univariable logistic regression to evaluate participant demographics, cancer characteristics, health behaviors, and COVID-19 specific items with odds of COVID-19 vaccine acceptance. We then conducted multivariable logistic regression including the factors that were statistically associated with vaccine acceptance in univariable models as outlined in Table 3 and Supplemental Table 1. We assessed frequencies of demographic characteristics and attitudes between participants with positive and negative discordance between T1 and T2 survey. Due to the exploratory nature of this analysis, we did not adjust for multiple comparisons. [34,35] All P-values were 2-sided with an $\alpha < 0.05$. Analyses were conducted using SAS, version 9.4 (SAS Institute Inc., Cary, North Carolina, United States).

3. Results

A total of 5,814 participants were included, of which 76.4% (n = 4,440) reported already receiving the COVID-19 vaccine at T1 and another 10.4% (n = 604) reported they would get the vaccine as soon as it was available to them (Table 1). Individuals aged 70–89 years (88.9%) were more likely to have received the vaccine than those aged 18–49 years (53.4%). Males were more likely to report getting the vaccine (80.5%) than females (73.5%). Receiving the flu shot versus not was also more prevalent among those who received COVID-19 vaccination (85.0% vs. 48.5%, respectively), as well as not having a confirmed COVID-19 infection (76.9% vs. 59.9% among those with a confirmed infection). Participants with hematologic malignancies were also more likely to report they received the vaccine than those with solid tumors (80.8% vs. 75.6%). Those who received the vaccine also had higher COVID-19 behavioral risk mitigation scores, indicating safer practices, than those who did not get the vaccine (mean score of 20.2 vs. 16.9).

Overall, low accepters of the vaccine were less likely to report they were extremely confident in the vaccine compared to high vaccine accepters (3.8% vs. 52.9%, p <.0001) (Table 2). Low accepters of the vaccine consistently reported more concerns than high accepters, specifically regarding the overall effectiveness of the vaccine (49.5% vs. 35.9%, p <.0001), getting a COVID-19 infection from the vaccine (15.8% vs. 2.7%, p <.0001), side effects (75.6% vs. 37.0%, p <.0001), rushed to the market too soon (42.1% vs. 8.1%, p <.0001), and interaction with medications (16.8% vs. 9.3%, p <.0001). Additionally, 20.4% of the low accepters said they would not trust any vaccine compared to 0.4% of the high accepters (p <.0001). Low accepters of the vaccine also reported that a vaccine with a one-time dose would motivate them more so than high accepters (p =.02), were less anxious about getting infected with COVID-19 (p <.0001), less worried about infecting others (p <.0001), and less worried about dying from COVID-19 (p <.0001) than high accepters. Cancer specific beliefs differed by vaccine acceptance such that 57% of high accepters and 41.5% of low accepters agreed or strongly agreed that having cancer puts them at greater risk for being infected or dying from COVID-19 (p <.0001). Further, fear of how the COVID-19 pandemic will impact their cancer care, recovery, or survivorship was seen more for high accepters (30.2% agree or strongly agree) compared to low accepters (26.9% agree or strongly agree, <0.0001).

In the fully adjusted multivariable model, which included significant predictors from the univariable model, older age was significantly associated with higher odds of vaccine acceptance (70–89 vs. 18–49: aOR: 2.57, 95% CI: 1.33, 4.86), though it was attenuated from the univariable model (comparable OR: 5.48; Table 3). Being male (vs. female: aOR: 1.28, 95% CI: 1.02, 1.60), having an income of ≥$60,000 (vs. <$60,000: aOR: 1.81, 95% CI: 1.41, 2.32) and greater perceived severity of COVID-19 (very serious vs. not at all serious: aOR: 2.55, 95% CI: 1.76, 3.70) also were associated with higher odds of vaccine acceptance, as well as practicing more risk mitigation behaviors (per one standard deviation increase: aOR: 1.75, 95% CI: 1.57, 1.95) and receiving the flu shot (vs. not received: aOR: 6.56, 95% CI: 5.25, 8.20). Individuals living with more than one other (vs. alone: aOR: 0.53, 95% CI: 0.35, 0.79) and those who were more socioeconomically disadvantaged (per 10 percentile points: aOR: 0.89, 95% CI: 0.85, 0.93) had lower odds of reporting vaccine acceptance. Marital status, living with one other person, race, ethnicity, employment status, insurance status, cancer type, age at last cancer diagnosis, smoking status, and daily life change due to COVID-19 were not statistically significant in the fully adjusted model. Results were similar in partially adjusted models (Supplemental Table 1).

More people had positive discordance (n = 170) than negative discordance (n = 15) between T1 and T2 surveys (Supplemental Table 2). Compared to those with positive discordance, those with negative discordance were slightly older, female, non-white race, Hispanic ethnicity, and more socioeconomically disadvantaged. Individuals with negative discordance had less concerns about the vaccine and were more confident that the vaccine was effective and safe during the T1 survey than those who had positive discordance (Supplemental Table 3).

4. Discussion

In a large study of over 5,000 individuals with a confirmed cancer diagnosis, most patients reported receiving or intention to receive the COVID-19 vaccine. We identified positive determinants of COVID-19 vaccine acceptance among this population, including older age, male sex, higher income, recent influenza vaccination receipt, higher COVID-19 specific risk mitigation behaviors, and higher perceived risk and severity of COVID-19. Conversely adults with lower socioeconomic status and those

Table 2
COVID-19 Vaccine Attitudes and Beliefs Among Patients with an Invasive Cancer Diagnosis in the U.S. by COVID-19 Vaccine Acceptance (n = 5,814; February 2021 – April 2021).

	High Accepters (n = 5,044, 86.8%)	Low Accepters (n = 770, 13.2%)	p-value
Are you confident that the COVID-19 vaccine(s) are effective and safe?			
Extremely confident	2667 (52.9)	29 (3.8)	**<0.0001**
Somewhat confident	2058 (40.8)	138 (17.9)	
Neither confident nor unconfident	216 (4.3)	168 (21.8)	
Not very confident	87 (1.7)	240 (31.2)	
Not confident at all	16 (0.3)	195 (25.3)	
Concerns about a COVID-19 vaccine? [a]			
Overall effectiveness	1809 (35.9)	381 (49.5)	**<0.0001**
Getting infected with COVID-19 from the vaccine	137 (2.7)	122 (15.8)	**<0.0001**
Not being able to afford it	32 (0.6)	9 (1.2)	0.0988
Safety or side effects	1864 (37.0)	582 (75.6)	**<0.0001**
It will be rushed to the market too soon	406 (8.1)	324 (42.1)	**<0.0001**
It will take too long to become available	197 (3.9)	15 (2.0)	**0.0069**
It may interact with my medications	467 (9.3)	129 (16.8)	**<0.0001**
I won't trust any COVID-19 vaccine	21 (0.4)	157 (20.4)	**<0.0001**
COVID-19 isn't a serious illness	27 (0.5)	29 (3.8)	**<0.0001**
I'm not worried about getting COVID-19	164 (3.3)	102 (13.3)	**<0.0001**
Stated other reason [b]	45 (0.9)	13 (1.7)	**0.0384**
I have no concerns about a COVID-19 vaccine	2802 (55.6)	51 (6.6)	**<0.0001**
How much would each of the following reasons motivate you to get a COVID-19 vaccine? [c]			
The vaccine was free and readily available			
A lot	3110 (64.4)	111 (14.7)	**<0.0001**
A little	825 (17.1)	154 (20.4)	
Not at all	896 (18.6)	491 (65.0)	
The vaccine was about 90% effective			
A lot	4350 (89.5)	209 (27.7)	**<0.0001**
A little	321 (6.6)	248 (32.9)	
Not at all	191 (3.9)	297 (39.4)	
Few people experienced any side effects			
A lot	3175 (66.7)	264 (35.2)	**<0.0001**
A little	1053 (22.1)	210 (28.0)	
Not at all	533 (11.2)	276 (36.8)	
The vaccine was a one-time dose			
A lot	1298 (29.1)	239 (31.6)	**0.0181**
A little	1050 (23.5)	200 (26.5)	
Not at all	2120 (47.5)	317 (41.9)	
Your doctor or health care professional recommended it			
A lot	3463 (73.0)	230 (30.6)	**<0.0001**
A little	632 (13.3)	244 (32.5)	
Not at all	652 (13.7)	278 (37.0)	
The CDC or FDA recommended it			
A lot	3254 (68.2)	98 (13.1)	**<0.0001**
A little	974 (20.4)	184 (24.5)	
Not at all	546 (11.4)	469 (62.5)	
The vaccine would help protect those I care about from getting sick			
A lot	4504 (92.7)	292 (38.6)	**<0.0001**
A little	248 (5.1)	264 (34.9)	
Not at all	105 (2.2)	200 (26.5)	
I feel anxious about getting COVID-19.			
Strongly disagree	547 (10.8)	201 (26.1)	**<0.0001**
Disagree	970 (19.2)	163 (21.2)	
Neither agree or disagree	1191 (23.6)	211 (27.4)	
Agree	1581 (31.3)	127 (16.5)	
Strongly agree	718 (14.2)	59 (7.7)	
I have already had COVID-19	37 (0.7)	9 (1.2)	
I worry about possibly infecting others.			
Strongly disagree	577 (11.4)	178 (23.1)	**<0.0001**
Disagree	925 (18.3)	163 (21.2)	
Neither agree or disagree	1218 (24.2)	207 (26.9)	
Agree	1639 (32.5)	172 (22.3)	
Strongly agree	685 (13.6)	50 (6.5)	
I am concerned about a family member or close friend getting or dying from COVID-19.			
Strongly disagree	299 (5.9)	132 (17.1)	**<0.0001**
Disagree	567 (11.2)	124 (16.1)	
Neither agree or disagree	843 (16.7)	177 (23.0)	
Agree	2177 (43.2)	226 (29.4)	
Strongly agree	1158 (23.0)	111 (14.4)	
I worry about the possibility of dying from COVID-19.			
Strongly disagree	808 (16.0)	258 (33.5)	**<0.0001**
Disagree	1138 (22.6)	166 (21.6)	
Neither agree or disagree	1230 (24.4)	169 (22.0)	
Agree	1254 (24.9)	119 (15.5)	
Strongly agree	614 (12.2)	58 (7.5)	

(*continued on next page*)

Table 2 (*continued*)

	High Accepters (n = 5,044, 86.8%)	Low Accepters (n = 770, 13.2%)	p-value
I fear how the COVID-19 pandemic will impact my cancer care, recovery, or survivorship.			
Strongly disagree	755 (15.0)	185 (24.0)	**<0.0001**
Disagree	1220 (24.2)	167 (21.7)	
Neither agree or disagree	1548 (30.7)	211 (27.4)	
Agree	1100 (21.8)	150 (19.5)	
Strongly agree	421 (8.4)	57 (7.4)	
I am concerned that cancer puts me at greater risk for being infected or dying from COVID-19.			
Strongly disagree	342 (6.8)	129 (16.8)	**<0.0001**
Disagree	674 (13.4)	134 (17.4)	
Neither agree or disagree	1156 (22.9)	188 (24.4)	
Agree	2091 (41.5)	236 (30.7)	
Strongly agree	781 (15.5)	83 (10.8)	
I feel I have no control over how COVID-19 will impact my life.			
Strongly disagree	609 (12.1)	122 (15.8)	**<0.0001**
Disagree	1736 (34.4)	185 (24.0)	
Neither agree or disagree	1057 (21.0)	196 (25.5)	
Agree	1264 (25.1)	198 (25.7)	
Strongly agree	378 (7.5)	69 (9.0)	
I know where to get accurate COVID-19 information that is specific to me as a cancer patient or survivor.			
Strongly disagree	141 (2.8)	38 (4.9)	**<0.0001**
Disagree	529 (10.5)	120 (15.6)	
Neither agree or disagree	853 (16.9)	178 (23.1)	
Agree	2555 (50.7)	317 (41.2)	
Strongly agree	966 (19.2)	117 (15.2)	

Percentages may not add to 100% due to rounding.
[a] Participants could check any reason that applied to them.
[b] Most common other reasons included poor health, effects on cancer diagnosis or treatment, and difficulty getting an appointment.
[c] Missingness due to non-completion of sub-questions and ranged from 182–576 for high accepters and 14–20 for low accepters.

living with more than one other person had lower odds of vaccine acceptance, potentially necessitating targeted educational efforts to ensure equitable delivery of the vaccine, particularly now in the context of COVID-19 vaccine boosters. We also found that cancer patients with low vaccine acceptance had more concerns about vaccination effectiveness, getting infected from the vaccine, side effects, being rushed to the market, and potential interactions with medications compared to high accepters of the vaccine. Similarly, a study in the general US population also found that low accepters of the COVID-19 had more concerns over potential side effects, suggesting this finding is not unique to cancer patients specifically. [12] Further, our findings are consistent with other studies such that misinformation surrounding the COVID-19 can significantly impact if a person decides to get vaccinated. [12,20,24,25,36–38].

Vaccination rates for influenza have shown to be higher among cancer patients than in the general population in the US. [39] Despite this, predictors of vaccine uptake in patients with cancer are largely similar to those in the general population. [10–12,15,20,21,23,25] Our study showed that individuals 70–89 years of age were more likely to accept the vaccine compared to those aged 18–49; however, this may be due to the initial roll out of the vaccine being primarily available to older individuals during the time period of this study. Nonetheless, this is a consistent finding across studies in the general population for COVID-19 and other vaccine types [10,11,21,25], indicating that targeted messaging toward younger individuals is needed to improve vaccine uptake. Similarly, ours and other studies observed that receiving or planning to get the flu shot was significantly associated with increased acceptance of the COVID-19 vaccine, suggesting that some individuals have vaccine hesitancy in general. [7,10,20,21,23].

We also found cancer patients who practiced more risk mitigation behaviors (e.g., safer practices) were more likely to accept the vaccine. Most patients in this study live in Florida and participated in these behaviors voluntarily as no risk mitigation policies were in effect at the time of the surveys. [40] Patients with cancer have previously been reported to better adhere to COVID-19-related recommended behaviors, such as hand washing, social distancing, and social quarantine, [41] which may then translate to a greater willingness to accept a vaccine. Notably, a study among patients with hematologic cancers found similar results to our study, in which those who were hesitant toward the vaccine were less likely to wear a face mask. [25].

With respect to COVID-19 perceptions, in the general population, adults were more likely to adhere to recommended COVID-19 preventive behaviors if they had a higher perceived risk of developing COVID-19. [42] This may be explained by the effects that psychological determinants such as past behaviors, experience, subjective norms, and perceived behavioral control has on vaccination behavior. [7] These psychological determinants may impact cancer patients more so than the general population due to cancer patients, especially patients with hematologic and lung cancer, having a greater risk of more severe SARS-CoV-2 infection and mortality from COVID-19. [43–45] Our study demonstrated the importance of risk perception of getting or having severe outcomes due to COVID-19 illness as we observed higher vaccine acceptance among individuals who perceived COVID-19 to be a serious outcome, which is in concordance with prior work. [12,15,22,25] We also observed that increased perceived cancer specific COVID-19 risk was associated with high vaccine acceptance and may indicate that improved communication with cancer patients on their COVID-19 risks could increase vaccination in this population.

Further, prior studies have shown that perceived COVID-19 severity for one's immediate network, including family, friends and co-workers, more highly influences intention to vaccinate than perceived risk of one's self. [46] We observed those who were high COVID-19 vaccine accepters agreed or strongly agreed that they were concerned with infecting others and concerned about a family member or close friend dying from COVID-19 more so than those who were low vaccine accepters. However, we found that

Table 3
Odds Ratios (OR) and 95% Confidence Interval (95% CI) of High Vaccine Acceptance Among Patients with an Invasive Cancer Diagnosis in the U.S. (n = 5,814).

	Univariable OR (95% CI)	Fully Adjusted Model [a] aOR (95% CI)
Demographics		
Age Quartiles		
18–49	Ref.	Ref.
50–59	1.15 (0.91, 1.45)	1.04 (0.70, 1.54)
60–69	**2.53 (2.02, 3.18)**	1.57 (0.95, 2.59)
70–89	**5.48 (4.29, 6.99)**	**2.57 (1.33, 4.86)**
Sex		
Females	Ref.	Ref.
Males	**1.46 (1.24, 1.71)**	**1.28 (1.02, 1.60)**
Race		
White	Ref.	Ref.
Non-white	**0.57 (0.44, 0.75)**	0.74 (0.51, 1.09)
Ethnicity		
Non-Hispanic	Ref.	Ref.
Hispanic	**0.67 (0.51, 0.88)**	1.10 (0.74, 1.61)
Marital Status		
Not married	Ref.	Ref.
Married	**1.39 (1.18, 1.65)**	1.06 (0.77, 1.46)
Living Arrangement		
Alone	Ref.	Ref.
Living with one other	**1.31 (1.05, 1.62)**	0.88 (0.59, 1.30)
Living with more than one other	**0.51 (0.40, 0.64)**	**0.53 (0.35, 0.79)**
National ADI (per 10 percentile point increase)	**0.87 (0.84, 0.90)**	**0.89 (0.85, 0.93)**
Employment Status		
Employed	Ref.	Ref.
Retired	**3.03 (2.55, 3.60)**	1.05 (0.78, 1.41)
Unemployed	0.85 (0.69, 1.05)	0.78 (0.57, 1.05)
Income		
<$60,000	Ref.	Ref.
≥$60,000	**1.91 (1.62, 2.26)**	**1.81 (1.41, 2.32)**
Unknown	**1.34 (1.07, 1.69)**	1.09 (0.80, 1.49)
Insurance Status		
Insured	Ref.	Ref.
Not insured	**0.48 (0.34, 0.68)**	1.13 (0.69, 1.86)
Healthcare Worker		
Never	Ref.	Ref.
Past	**1.46 (1.00, 2.11)**	1.11 (0.69, 1.80)
Current	0.85 (0.54, 1.32)	1.30 (0.69, 2.46)
Cancer Characteristics		
Cancer Type at Most Recent Diagnosis		
Solid tumor	Ref.	Ref.
Hematologic malignancy	**1.34 (1.07, 1.69)**	0.87 (0.65, 1.16)
Age at Last Cancer Diagnosis (per 10 years increase)	**1.57 (1.47, 1.67)**	1.03 (0.87, 1.22)
Health Behaviors		
Received Flu Shot for 2020–2021		
No	Ref.	Ref.
Yes, got it	**9.63 (8.07, 11.49)**	**6.56 (5.25, 8.20)**
Yes, plan to get it	**7.17 (4.79, 10.75)**	**5.53 (3.43, 8.92)**
Not sure	**2.09 (1.54, 2.82)**	**2.05 (1.42, 2.97)**
Smoking Status		
Never	Ref.	Ref.
Past	**1.48 (1.26, 1.74)**	1.00 (0.80, 1.25)
Current	**0.55 (0.39, 0.77)**	0.85 (0.52, 1.40)
Risk mitigation behaviors (per one SD)	**1.92 (1.79, 2.06)**	**1.75 (1.57, 1.95)**
COVID-19 Specific Characteristics		
COVID-19 Positivity [b]		
Never tested/tested negative	Ref.	Ref.
Tested positive	**0.46 (0.32, 0.65)**	–
Risk Perception of Contracting COVID-19		
Very unlikely	Ref.	Ref.
Somewhat unlikely	**1.56 (1.24, 1.96)**	**1.51 (1.11, 2.05)**
Neither unlikely or likely	**1.25 (1.02, 1.55)**	**1.35 (1.02, 1.79)**
Somewhat likely	1.28 (0.99, 1.66)	**1.48 (1.04, 2.09)**
Very likely	0.90 (0.57, 1.42)	0.96 (0.52, 1.77)
Severity of COVID-19		
Not at all	Ref.	Ref.
Somewhat	**4.25 (3.33, 5.42)**	**2.03 (1.44, 2.85)**
Very	**8.14 (6.37, 10.41)**	**2.55 (1.76, 3.70)**
Daily life change due to COVID-19		
Not at all	Ref.	Ref.
A little	1.58 (0.96, 2.62)	0.77 (0.38, 1.56)
Somewhat	**2.49 (1.52, 4.06)**	0.86 (0.43, 1.73)
A moderate amount	**3.24 (2.00, 5.24)**	0.79 (0.39, 1.58)
A lot	**5.12 (3.16, 8.29)**	0.97 (0.48, 1.97)

*Abbreviations: ADI: Area Deprivation Index, SD: Standard Deviation.

[a] Fully Adjusted Model: Demographic characteristics (age, gender, marital status, living arrangement, race, ethnicity, National Area Deprivation Index, income, insurance status, health care worker), cancer characteristics (cancer type, age at cancer diagnosis), health behaviors (flu shot status, smoking status, risk mitigation behaviors), COVID-19 specific characteristics (COVID-19 positivity, risk perception of contracting COVID-19, severity of COVID-19, daily life change due to COVID-19).
[b] COVID-19 positivity was not included in the fully adjusted model as risk perception of contracting COVID-19 and severity of COVID-19 was only asked to those who had not been infection with COVID-19.

those who lived with at least two others in their house are less likely to be vaccine accepters, which remained highly significant even after multivariate adjustment. This finding was unexpected and future research should examine factors that may be associated with living arrangement and vaccine acceptance.

A prior study found that those who were socioeconomically disadvantaged were more likely to believe COVID-19 misinformation. [38] Consistent with this, we observed that cancer patients living in socioeconomically disadvantaged areas had lower odds of vaccine acceptance. This suggests that COVID-19 vaccine misinformation, lack of access to reliable healthcare, and medical mistrust may be playing a role in vaccine uptake among this group, even in those with cancer who may have more interaction with the health system. Since socioeconomically disadvantaged individuals also have higher incidence rates of COVID-19 infection and higher mortality, [47] more work is needed to address this gap. Further, the majority of low accepters of the COVID-19 vaccine stated recommendation by their doctor, healthcare professional, CDC, or FDA would not motivate them to get the vaccine. Despite the population of cancer patients having more contact with healthcare, medical mistrust and misinformation may still have a substantial impact on vaccine acceptance. Targeted messages to increase vaccine uptake typically focuses on beliefs and intentions and have been shown to increase intentions; however, limited research has shown actual benefit on vaccine uptake. [5] Future work should consider a multi-level framework to address several areas surrounding vaccine intention and uptake.

This study has many strengths, including a large sample size, integrated data from medical records and Cancer Registry, and multiple self-reported behaviors, attitudes, and beliefs allowing assessment of vaccine acceptance predictors across multiple pathways. However, this study was limited as it included mostly white, non-Hispanic individuals with higher income, most of which lived in the state of Florida. Future work should focus on minority populations to better understand vaccine acceptance among this group. This study was also limited by the self-reported nature of COVID-19 vaccine acceptance as social desirability bias may have led to an increase in reporting high vaccine acceptance; however, the rate of vaccine acceptance in this study was similar to the vaccination rates for at least one dose of adults over age 18 in the general U.S. population, though it is higher than the vaccination rates in Florida. [48] This may also be due to the respondents being older, with response rates highest for those aged 70–89 years old and lowest for patients aged 18–49. We characterized patients as high or low accepters of the vaccine based actual uptake or intent to have the vaccine. This may not equate to receiving the vaccine, as we saw both positive and negative discordance between the two follow-up periods.

Overall, this is the largest study investigating at sociodemographic and behavioral factors that influence COVID-19 vaccine uptake among cancer patients. Our findings suggest, that similar to the general population, targeted interventions to improve vaccine acceptance in patients with cancer should focus on younger individuals, those living with multiple other individuals, and those who have more socioeconomic disadvantage. Specific multi-level interventions should focus on issues related to concerns about vaccine effectiveness, safety/side effects, and lack trust in any COVID vaccine. These findings highlight the need to educate cancer patients on their risk of COVID infection and the benefits of vaccination in this population.

Data availability

Data will be made available on request.

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.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.vaccine.2022.09.063.

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