


# Factors associated with timely COVID-19 vaccination in a population-based cohort of patients with cancer

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## Abstract

**Background:** In many jurisdictions, cancer patients were prioritized for COVID-19 vaccination because of increased risk of infection and death. To understand sociodemographic disparities that affected timely receipt of COVID-19 vaccination among cancer patients, we undertook a population-based study in Ontario, Canada.

**Methods:** Patients older than 18 years and diagnosed with cancer January 2010 to September 2020 were identified using administrative data; vaccination administration was captured between approval (December 2020) up to February 2022. Factors associated with time to vaccination were evaluated using multivariable Cox proportional hazards regression.

**Results:** The cohort consisted of 356 535 patients, the majority of whom had solid tumor cancers (85.9%) and were not on active treatment (74.1%); 86.8% had received at least 2 doses. The rate of vaccination was 25% lower in recent (hazard ratio [HR] = 0.74, 95% confidence interval [CI] = 0.72 to 0.76) and nonrecent immigrants (HR = 0.80, 95% CI = 0.79 to 0.81). A greater proportion of unvaccinated patients were from neighborhoods with a high concentration of new immigrants or self-reported members of racialized groups (26.0% vs 21.3%, standardized difference = 0.111,  $P < .001$ ), residential instability (27.1% vs 23.0%, standardized difference = 0.094,  $P < .001$ ), or material deprivation (22.1% vs 16.8%, standardized difference = 0.134,  $P < .001$ ) and low socioeconomic status (20.9% vs 16.0%, standardized difference = 0.041,  $P < .001$ ). The rate of vaccination was 20% lower in patients from neighborhoods with the lowest socioeconomic status (HR = 0.82, 95% CI = 0.81 to 0.84) and highest material deprivation (HR = 0.80, 95% CI = 0.78 to 0.81) relative to those in more advantaged neighborhoods.

**Conclusions:** Despite funding of vaccines and prioritization of high-risk populations, marginalized patients were less likely to be vaccinated. Differences are likely due to the interplay between systemic barriers to access and cultural or social influences affecting uptake.

COVID-19 presents a substantial threat to the health of people with cancer. Reports published to date demonstrate higher infection rates (1), greater risk for severe disease (2), and higher rates of death compared with age-matched controls (3,4). As a result, patients with cancer, particularly those with newly diagnosed hematological malignancies, or those receiving treatment with hematopoietic stem cell transplant or immunosuppressive agents were prioritized for vaccination against COVID-19 in many jurisdictions (5,6). Although patients in the survivorship or remission phase of the cancer trajectory have not been shown to be at higher risk of COVID-19 infection, they have been shown to be at a higher risk of developing serious complications and requiring hospitalization compared with matched noncancer controls (7). Emerging studies demonstrate disparities in COVID-19 vaccine

access and uptake across the globe within the general population, with vaccination rates varying from 28% to 86.1% (8); however, it remains unclear what disparities persisted among the cancer patient population.

There are both system-level and individual-level factors that influence both access to and uptake of vaccinations. Sociodemographic determinants of health that have long limited equitable access to care—such as being older, having greater material deprivation, having a disability, being a member of a racialized group, living alone or in multi-generational households (9), and being an immigrant, particularly from a low- or middle-income country (10)—are also associated with statistically significantly lower odds of being vaccinated. Furthermore, operational and supply chain challenges have further impeded timely access

to COVID-19 vaccines in many jurisdictions (11,12). Many jurisdictions globally have adopted policies (13) prioritizing high-risk and marginalized populations (14,15) for receipt of vaccines. In Ontario, Canada, in addition to clinically defined high-risk groups including patients with cancer, Indigenous people, those living in congregate settings, and those residing in neighborhoods in areas with high COVID-19 positivity rates or with high proportions of essential workers were also prioritized for vaccination (5). However, it is unknown to what degree vaccine inequities persisted among patients with cancer.

As more immune escape variants of the virus emerge, it is increasingly important to ensure that these high-risk patients receive third and even fourth doses of the vaccine (16). We undertook a population-based study to evaluate the extent of COVID-19 vaccine uptake and factors associated with time to receipt of full vaccination (2 doses) and third doses among patients diagnosed with cancer, with a focus on equity to inform better planning moving forward.

## Methods

### Cohort identification

Ontario, Canada has a population of 14.8 million individuals and a single-payer, universal health-care system whereby COVID-19 vaccines were directly funded by the government. The study was approved by the Sunnybrook Health Sciences Centre Research Ethics Board before initiation. The cohort was identified using the Ontario Cancer Registry deterministically linked to other administrative data holdings at ICES (formerly the Institute for Clinical Evaluative Sciences), which consistently and completely captures care episodes for Ontario residents (17). Patients were included in the cohort if they were 18 years and older, residents of Ontario, and were diagnosed with cancer between January 1, 2010, and September 30, 2020. Patients were excluded if they had unspecified or benign disease or if their date of death was before vaccine approval in Canada (December 9, 2020). Patients were considered to be vaccinated if they had received 2 doses. For third doses, the cohort was restricted to patients who were alive when they became eligible to receive their doses, defined as 56 days having elapsed since receipt of their second doses as recommended by Public Health Ontario. Information on vaccination administration from vaccine approval (December 9, 2020) to January 31, 2022, was obtained from the Ontario COVID-19 Vaccine database.

### Variable creation

Demographic information (age, sex, postal code) and date of death were obtained from the Registered Persons Database. Information on immigration status was obtained from the Immigration, Refugees and Citizenship Canada database, which captures information on permanent and temporary residents of Canada as well as on citizenship and immigration programs. Patients were categorized as being recent (immigrated in the last 10 years) or nonrecent (immigrated since 1985) immigrants or were considered long-term residents/Canadian born. Based on postal code, patients were categorized as living in an urban or a rural location. Socioeconomic quintile for those residing in urban areas was assigned based on census data based on postal code. Comorbidity burden was assessed using the Johns Hopkins' Aggregated Diagnosis Group (ADG) system (18) as a measure of non-cancer health-care resource use. Patients were categorized as having a low (1-4 ADGs), moderate (5-9 ADGs), or high (10+ ADGs) comorbidity burden. Patients were considered to be a resident of a long-term care home if they had a record for a long-

term care facility in the Home Care database. Receipt of recent (within 6 months of vaccine approval date of December 9, 2020) systemic therapy was obtained from Ontario Health Insurance Plan physician billing data. Patients were considered to have had a positive COVID-19 test before vaccination if they had a record for a positive test in the Ontario Laboratory Services COVID-19 database before the date of their first vaccine dose. Patients were assigned to 1 of 10 regional public health units based on the postal code of their residence.

### Marginalization

Quintiles of each of the dimensions of the Ontario Marginalization Index (Residential Instability, Material Deprivation, Dependency, Ethnic Concentration) were derived based on postal code (19). Each dimension of marginalization is a composite measure assembled from census data at the dissemination area level. Residential Instability is a measure of family and housing instability based on the type and density of residential accommodations and family characteristics. Material Deprivation is a measure of poverty based on income, housing quality, education, and family structure. Dependency measures the proportion of residents without employment income, including seniors and those receiving disability benefits. Ethnic Concentration is a measure of the proportion of residents who are recent immigrants and/or self-report belonging to a racialized group.

### Statistical analysis

Demographic and clinical characteristics were summarized using descriptive statistics; vaccinated and unvaccinated patients were compared using  $\chi^2$ , 1-way ANOVA, and Kruskal-Wallis tests as appropriate; tests were 2-sided. Cumulative incidence plots were generated estimating probability against time to vaccination in days from December 9, 2020, for full vaccination (receipt of 2 doses) or from the date individual patients became eligible for third doses, as appropriate.

Adjusted associations between patient characteristics and time to vaccination were evaluated using Cox proportional hazards regression. Because residents of long-term care facilities were prioritized for early access to first and second doses of the vaccine, second-dose models were stratified by this covariate to address issues with effect modification. Additionally, because associations between time since diagnosis and time to vaccination were found to be affected by whether the patient had a solid vs a hematological malignancy as well as if they received recent treatment with systemic therapy, interaction terms between these variables were included in the models. Results are reported as hazard ratios (HR) with 95% confidence intervals (CIs). Variables included time since cancer diagnosis to index, age (cubic spline), sex, immigration status, COVID-19 infection before vaccination, 3 composite measures of marginalization, recent systemic therapy, comorbidities, socioeconomic status, long-term care residency, and regional public health authority. Because time to third dose was likely affected by the omicron variant surge and how quickly patients received their second dose, these were included as time-varying covariates in the booster model. Satisfaction of the proportional hazards assumption was confirmed by examining scaled Schoenfeld residuals. All analyses were completed using SAS EG (version: 7.1; Toronto, Canada);  $P < .05$  was considered statistically significant.

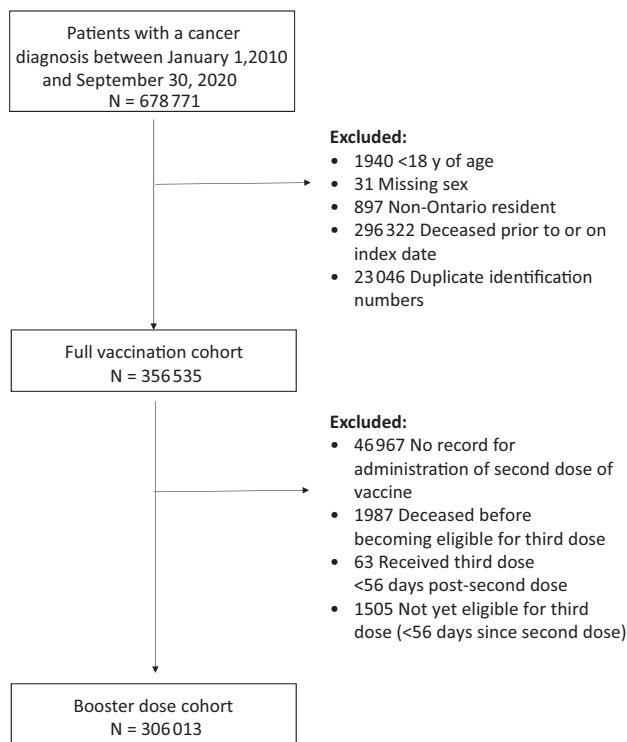


Figure 1. Cohort creation.

## Results

### Cohort description

The full cohort consisted of 356 535 patients (Figure 1), of which 11.5% (40 971) were unvaccinated; 86.8% of patients were fully vaccinated and 66.8% had received a third dose. The mean age was 66 years (standard deviation: 14.4; Table 1); most of the patients were female (64.2%), diagnosed with solid tumors (85.9%), Canadian-born or long-time residents (90.8%), and had a moderate comorbidity burden (45.0%).

### Characteristics of unvaccinated patients

Compared with those who had received at least 1 vaccine dose (Table 1), a greater proportion of unvaccinated patients were male (39.5% vs 35.4%, standardized difference = 0.086,  $P < .001$ ), recent (3.8% vs 1.9%; standardized difference = 0.110,  $P < .001$ ) or nonrecent immigrants (10.1% vs 6.6%, standardized difference = 0.127,  $P < .001$ ), and had a lower comorbidity burden (0-4 aggregated diagnosis groups = 37.8% vs 22.4%, standardized difference = 0.34,  $P < .001$ ). Additionally, a greater proportion of unvaccinated patients were from neighborhoods with high Ethnic Concentration (26.0% vs 21.3%, standardized difference = 0.111,  $P < .001$ ), low socioeconomic status (20.9% vs 16.0%, standardized difference = 0.041,  $P < .001$ ), and high Residential Instability (27.1% vs 23.0%, standardized difference = 0.094,  $P < .001$ ) or Material Deprivation (22.1% vs 16.8%, standardized difference = 0.134,  $P < .001$ ) compared with those who had received at least 1 dose of the vaccine.

### Associations between clinical characteristics and rate of vaccination

A greater proportion of patients with more remote cancer diagnoses received both full vaccination and third doses compared with recently diagnosed patients (diagnosed in the last year; Figure 2). Patients with hematological cancers took less time to get

vaccinated than patients with solid tumor cancers; for patients diagnosed in the last year, those with hematological malignancies received full vaccination 20% faster than those with solid tumors (HR = 1.20, 95% CI = 1.16 to 1.24; Table 2) and third doses 37% faster (HR = 1.37, 95% CI = 1.32 to 1.43). There was little difference in the rate of receipt of full vaccination or third doses between those recently treated with systemic therapy and those who were not, except in patients with latent cancer diagnoses (diagnosed 5-10 years prior), where patients recently treated with systemic therapy received their vaccinations 11%-12% faster than those without recent treatment (full vaccination: HR = 1.12, 95% CI = 1.12 to 1.14; third dose: HR = 1.11, 95% CI = 1.09 to 1.13). Having a moderate (HR = 1.36, 95% CI = 1.35 to 1.38) or high (HR = 1.30, 95% CI = 1.29 to 1.32) comorbidity burden or having a COVID-19 infection before first dose (HR = 1.12, 95% CI = 1.10 to 1.15) was associated with a higher rate of receipt of full vaccination; similar findings were observed for third doses.

### Associations between sociodemographic determinants of health and rate of vaccination

Compared with patients who were Canadian born, the rate of full vaccination was found to be approximately 20%-25% lower for recent (HR = 0.74, 95% CI = 0.72 to 0.76) or nonrecent immigrants (HR = 0.80, 95% CI = 0.79 to 0.81); similar findings were observed for third doses (recent: HR = 0.67, 95% CI = 0.65 to 0.70; nonrecent: HR = 0.71, 95% CI = 0.70 to 0.73). Additionally, relative to patients in the most advantaged quintiles, the rate of full vaccination was approximately 20% lower in those patients in the lowest socioeconomic status quintile (HR = 0.82, 95% CI = 0.81 to 0.84) and those residing in neighborhoods with highest Material Deprivation (HR = 0.80, 95% CI = 0.78 to 0.82). Residential Instability was not associated with the rate of receipt of full vaccination (HR = 1.02, 95% CI = 1.00 to 1.03) but did affect receipt of third doses, whereby rate of vaccination was approximately 10% higher in those residing in the most Residentially Instable quintile than those in the most advantaged quintile (HR = 1.12, 95% CI = 1.10 to 1.14). Compared with the most advantaged quintile, those experiencing the most Material Deprivation had rates of vaccination approximately 20% lower for both full vaccination (HR = 0.80, 95% CI = 0.78 to 0.81) and third doses (HR = 0.81, 95% CI = 0.80 to 0.83). Conversely, those in the highest Dependency quintile had a higher rate of vaccination that those in the most advantaged quintile for both full vaccination (HR = 1.13, 95% CI = 1.12 to 1.15) and third doses (HR = 1.07, 95% CI = 1.06 to 1.09). Neighborhood Ethnic Concentration had no impact on rate of full vaccination (HR = 1.00, 95% CI = 0.99 to 1.02) and only a marginal impact on receipt of third doses (HR = 0.97, 95% CI = 0.95 to 0.99). Rate of receipt of vaccinations differed by geographical location, particularly for third doses (HR range = 0.85-1.28).

## Discussion

Our findings suggest that the provincial prioritization policy did achieve some of its intended aims because those identified as high risk of COVID-19 infection or mortality at the outset of the pandemic (20), particularly those of advanced age, diagnosed with hematological malignancies, having a high comorbidity burden, or living in long-term care facility, had higher rates of receipt of vaccination. Compared with patients with solid tumors, rate of receipt of vaccination of patients with hematological cancers was fastest in patients with newly diagnosed malignancies. This difference likely reflects clinical guidance to vaccinate patients before initiating treatment with lympho-depleting therapies (21)

**Table 1.** Demographics and clinical characteristics of cohort<sup>a</sup>

Variable	Full-vaccination cohort (n = 356 535)				P	Third-dose cohort (n = 306 212)
	Overall (n = 356 535)	Vaccinated (n = 315 564)	Unvaccinated (n = 40 971)	Standardized difference		
Age						
Mean (SD)	66 (14.4)	66 (14.2)	65 (15.8)	0.072	<.001	66 (14.1)
Median (IQR)	67 (57,76)	67 (57,76)	66 (55,76)	0.063	<.001	67 (57,76)
Sex, no. (%)					<.001	
Male	127 769 (35.8)	111 585 (35.4)	16 184 (39.5)	0.086		107 624 (35.1)
Female	228 766 (64.2)	203 979 (64.6)	24 787 (60.5)	0.086		198 588 (64.9)
Cancer type, No. (%)					<.001	
Solid tumor	306 337 (85.9)	271 304 (86.0)	35 033 (85.5)	0.013		263 387 (86.0)
Hematological	50 198 (14.1)	44 260 (14.0)	5938 (14.5)	0.013		42 825 (14.0)
Time since diagnosis, No. (%)					<.001	
Less than 1 y	35 828 (10.0)	30 948 (9.8)	4880 (11.9)	0.066		29 497 (9.6)
1-5 y	162 899 (45.7)	145 371 (46.1)	17 528 (42.8)	0.024		140 925 (46.0)
5-10 y	157 808 (44.3)	139 245 (44.1)	18 563 (45.3)	0.068		135 790 (44.3)
Recent systemic therapy, No. (%)	92 177 (25.9)	81 257 (25.7)	10 920 (26.7)	0.021	<.001	77 934 (25.5)
Immigration status, No. (%)					<.001	
Recent	7646 (2.1)	6105 (1.9)	1541 (3.8)	0.11		5890 (1.9)
Nonrecent	25 008 (7.0)	20 865 (6.6)	4143 (10.1)	0.127		20 176 (6.6)
Canadian/long-time resident	323 881 (90.8)	288 594 (91.5)	35 287 (81.0)	0.169		280 146 (91.5)
Socioeconomic status, No. (%)					<.001	
Q1 (lowest)	58 951 (16.5)	50 388 (16.0)	8563 (20.9)	0.041		48 423 (15.8)
Q2	62 447 (17.5)	54 697 (17.3)	7750 (18.9)	0.013		52 939 (17.3)
Q3	61 864 (17.4)	54 937 (17.4)	6927 (16.9)	0.056		53 377 (17.4)
Q4	62 058 (17.4)	55 677 (17.6)	6381 (15.6)	0.101		54 194 (17.7)
Q5 (highest)	67 482 (18.9)	61 122 (19.4)	6360 (15.5)	0.023		59 718 (19.5)
Rural	42 929 (12.0)	38 073 (12.1)	4855 (11.8)	0.127		36 913 (12.1)
Missing	805 (0.2)	670 (0.2)	135 (0.3)	0.007		648 (0.2)
Comorbidities, No. (%)					<.001	
0-4 ADGs	86 140 (24.2)	70 664 (22.4)	15 476 (37.8)	0.34		69 011 (22.5)
5-9 ADGs	160 478 (45.0)	146 913 (46.6)	13 565 (33.1)	0.042		143 280 (46.8)
10+ ADGs	109 917 (30.8)	97 987 (31.1)	11 930 (29.1)	0.277		93 921 (30.7)
Long-term care resident, No. (%)	5220 (1.5)	4724 (1.5)	496 (1.2)	6.247	<.001	4305 (1.4)
Residential Instability quintile, No. (%)					<.001	
Q1 (highest)	66 252 (18.6)	59 113 (18.7)	7139 (17.4)	0.034		57 691 (18.8)
Q2	67 611 (19.0)	60 475 (19.2)	7136 (17.4)	0.045		59 825 (19.2)
Q3	68 848 (19.3)	61 479 (19.5)	7369 (18.0)	0.038		59 707 (19.5)
Q4	67 327 (18.9)	59 524 (18.9)	7803 (19.0)	0.005		57 694 (18.8)
Q5 (lowest)	83 755 (23.5)	72 651 (23.0)	11 104 (27.1)	0.094		70 058 (22.9)
Missing	2742 (0.8)	2322 (0.7)	420 (1.0)	0.031		2237 (0.7)
Material Deprivation quintile, No. (%)					<.001	
Q1 (highest)	81 287 (22.8)	73 510 (23.3)	7777 (19.0)	0.106		71 701 (23.4)
Q2	75 679 (21.2)	67 802 (21.5)	7877 (19.2)	0.056		66 031 (21.6)
Q3	69 055 (19.4)	61 310 (19.4)	7745 (18.9)	0.013		59 514 (19.4)
Q4	65 709 (18.4)	57 605 (18.3)	8104 (19.8)	0.039		55 758 (18.2)
Q5 (lowest)	62 063 (17.4)	53 015 (16.8)	9048 (22.1)	0.134		50 971 (16.6)
Missing	2742 (0.8)	2322 (0.7)	420 (1.0)	0.031		2237 (0.7)
Dependency quintile, No. (%)					<.001	
Q1 (highest)	68 608 (19.2)	60 011 (19.0)	8597 (21.0)	0.052		58 268 (19.0)
Q2	63 608 (17.9)	56 253 (17.8)	7670 (18.7)	0.046		54 630 (17.8)
Q3	63 002 (17.7)	55 573 (17.7)	7249 (17.7)	0.033		54 163 (17.7)
Q4	66 692 (18.7)	59 231 (18.8)	7461 (18.2)	0.003		57 503 (18.8)
Q5 (lowest)	91 568 (25.7)	81 994 (26.0)	9574 (23.4)	0.111		79 411 (25.9)
Missing	2742 (0.8)	2322 (0.7)	420 (1.0)	0.031		2237 (0.7)
Ethnic Concentration quintile, No. (%)					<.001	
Q1 (highest)	71 699 (20.1)	64 211 (20.3)	7488 (18.3)	0.052		62 304 (20.3)
Q2	68 388 (19.2)	61 181 (19.4)	7207 (17.6)	0.046		59 442 (19.4)
Q3	66 520 (18.7)	59 333 (18.8)	7187 (17.5)	0.033		57 632 (18.8)
Q4	69 484 (19.5)	61 455 (19.5)	8029 (19.6)	0.003		59 681 (19.5)
Q5 (lowest)	77 702 (21.8)	67 062 (21.3)	10 640 (26.0)	0.111		64 916 (21.2)
Missing	2742 (0.8)	2322 (0.7)	420 (1.0)	0.031		2237 (0.7)
COVID-19 infection before vaccination, No. (%)	6658 (1.9)	6658 (1.9)	—	—	—	6292 (2.1)
Regional Public Health Authority, No. (%)					<.001	
Central East	28 345 (8.0)	25 347 (8.0)	2998 (7.3)	0.027		24 551 (8.0)
Central West	69 665 (19.5)	61 921 (19.6)	7744 (18.9)	0.018		60 098 (19.6)
Durham	16 467 (4.6)	14 724 (4.7)	1743 (4.3)	0.020		14 336 (4.7)
Eastern	26 082 (7.3)	23 396 (7.4)	2686 (6.6)	0.034		22 728 (7.4)
North	23 362 (6.6)	20 791 (6.6)	2571 (6.3)	0.013		20 079 (6.6)

(continued)



Table 1. (continued)

Variable	Full-vaccination cohort (n = 356 535)				P	Third-dose cohort (n = 306 212)
	Overall (n = 356 535)	Vaccinated (n = 315 564)	Unvaccinated (n = 40 971)	Standardized difference		
Ottawa	22 774 (6.4)	20 555 (6.5)	2219 (5.4)	0.046		20 006 (6.5)
Peel	28 625 (8.0)	24 724 (7.8)	3901 (9.5)	0.060		23 971 (7.8)
South West	46 234 (13.0)	40 978 (13.0)	5256 (12.8)	0.005		39 711 (13.0)
Toronto	66 712 (18.7)	58 048 (18.4)	8664 (21.1)	0.069		56 329 (18.4)
York	28 269 (7.9)	25 080 (7.9)	3189 (7.8)	0.006		24 403 (8.0)
Receipt of vaccinations, No. (%)					—	
One dose	5996 (1.7)	5996 (1.9)	—	—		—
Two doses	71 464 (20.0)	71 464 (22.6)	—	—		68 170 (22.3)
Three doses	238 104 (66.8)	238 104 (75.5)	—	—		238 042 (77.7)
Unvaccinated	40 971 (11.5)	—	40 971 (100)	—		—

<sup>a</sup> ADG = aggregated diagnosis groups; IQR = interquartile range.

due to increased risk of severe infection and death (22), and concerns with decreased immunogenicity and vaccine efficacy within this patient population after treatment (23). However, despite prioritization of patients receiving systemic therapy for vaccination, there was little difference in the rate of receipt of full vaccination or third doses between those recently treated with systemic therapy and those who were not, except in patients with latent cancer diagnoses (diagnosed 5-10 years prior). This may reflect clinical guidance to time COVID-19 vaccinations so they are between cycles of treatment or to delay vaccination until 1 month following completion of systemic therapy in those receiving treatment (21).

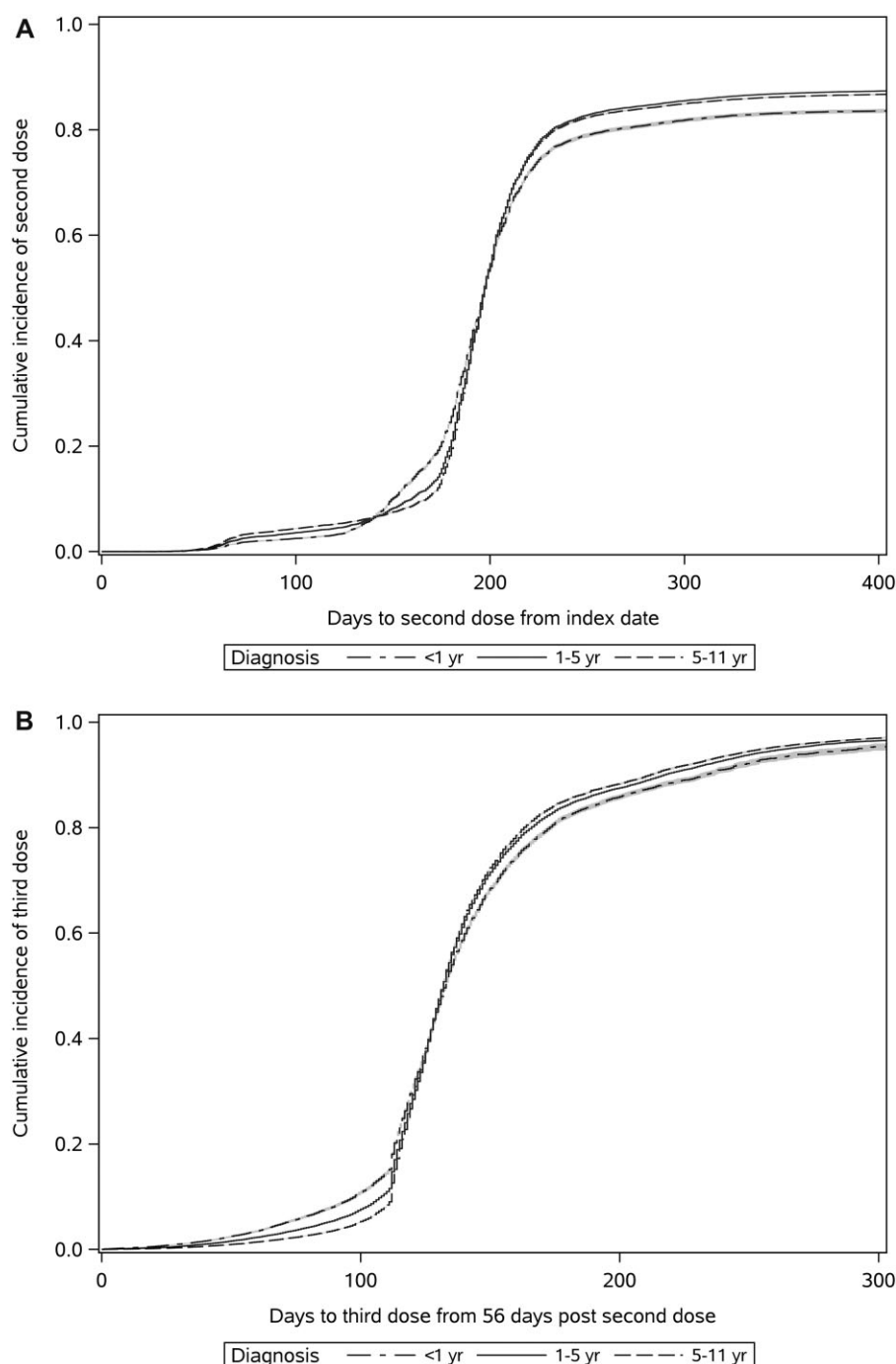
Even within the prioritized cancer population, disparities in receipt of COVID-19 vaccination in marginalized populations persisted. Similarly to other jurisdictions (24), we found that despite having an increased risk of exposure and infection (25-27), higher proportions of recent immigrants; those from neighborhoods with high Ethnic Concentrations, Residential Instability, and Material Deprivation; or those of low socioeconomic status were unvaccinated. It took longer for immigrants to receive full vaccination and booster doses than long-time residents. Additionally, it took longer for patients in the lowest socioeconomic strata or highest Material Deprivation quintiles to receive full vaccination and booster doses than those who were most advantaged. Despite direct government funding of COVID-19 vaccines and distribution policies aimed at prioritizing high-risk populations, marginalized patients with cancer were less likely to be vaccinated than other patients with cancer. To our knowledge, this is the first article to examine COVID-19 vaccine equity within the cancer patient population.

Observed disparities in receipt of vaccination are likely due to an inter-play between systemic barriers to access (physical barriers to accessible care, transportation challenges, long work hours, barriers in navigating the health-care system) as well as socio-cultural influences limiting uptake (inability of the health-care system to demonstrate trustworthiness, lack of access to professional translator services and lack of linguistic and cultural diversity among the health-care force, religion, education, preferences for alternative medicine, exposure to information or misinformation on vaccine-related adverse effects and deaths) (28-31). Particularly during the current pandemic, exposure to online medical misinformation regarding vaccine efficacy and side effects and through social media has been widespread and associated with increased vaccine hesitancy and vaccine refusal (32).

Reliance on current, area-based datasets rather than routinely collected, individual-level sociodemographic data makes it challenging to effectively identify high-risk populations, design

appropriate interventions, or test their impact (33). As such, there is a paucity of concrete examples from the literature of interventions that effectively overcome barriers to accessing health care. In future health emergencies, and should additional booster doses be warranted, marginalized populations and those at highest risk should continue to be prioritized and allocation processes must be transparent (34). Community partnerships should be leveraged to develop policies and interventions through participatory design that are sensitive to community needs, unique barriers, and cultural characteristics (35). Use of mobile clinics in neighborhoods with high risk of exposure (36,37) and community-based models that engage leaders and health-care providers that are representative of the racialized populations they serve have been successful strategies to improve rates of COVID-19 vaccination (38). To better meet patient needs, immunizations should be offered at a greater variety of times and points of contact within the health-care system (39). However, these strategies should be embedded within a more comprehensive plan that addresses the underlying inequities that put marginalized groups at higher risk of infection in the first place and through programs aimed at improving employment conditions, housing security, and social service systems (40). Additionally, formal evaluations grounded in equity frameworks (41-43) are needed to ascertain the impacts of interventions to improve inequities and inform future policy and interventions (43).

Our study must be taken in the context of its limitations. We used routinely collected, administrative data holdings to examine vaccination across Ontario residents who are enrolled in the provincial health insurance plan. With the exception of immigration status, which is collected at the individual level, other characteristics of marginalization that we examined are based on census data for dissemination area, which may affect the validity of our findings. Some sociodemographic factors associated with inequities in accessing health care, such as gender identity, sexuality, race, and Indigenous status (44), are either poorly captured or not readily available within the administrative data. Additionally, administrative data do not allow for the inference of causality, so it is difficult to ascertain whether observed differences in vaccination rates are related to issues of access to care or willingness to be vaccinated against COVID-19. We undertook multivariable analyses examining associations between individual clinical and demographic characteristics and rate of vaccination; however, future work should examine issues of intersectionality affecting vaccine access and uptake by evaluating social patterning and the interaction between different sociodemographic characteristics (45). Finally, we report on differences in rate and receipt of COVID-19 vaccination in marginalized groups relative to those



**Figure 2.** Cumulative incidence plots estimating probability against time to receipt of full vaccination from the date of vaccine approval (A), and third dose from when the patient became eligible (56 days following receipt of dose 2; B).

who are more advantaged; however, future work should focus on understanding drivers of lower rates of vaccination of these groups to inform future policies and interventions to address these inequities.

Despite direct government funding of COVID-19 vaccines and distribution policies aimed at prioritizing high-risk populations, marginalized patients with history of cancer were less likely to be vaccinated than other patients with cancer. Differences in receipt of vaccination are likely due to the interplay between systemic barriers to access (lack of trustworthiness of the health-care system, transportation barriers, work schedules), and cultural/social influences affecting uptake. Future efforts should work directly

with members of high-risk communities to understand how to improve vaccine delivery among these communities.

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**Table 2.** Factors associated with receipt of full vaccination and booster doses based on multivariable Cox proportional hazards models with interaction terms for time since diagnosis with cancer type and receipt of recent systemic therapy<sup>a</sup>

Variables	Full vaccination (n = 356 535) HR (95% CI)	Booster doses (n = 306 212) HR (95% CI)
Age		
Point estimate at 40 y	1.06 (1.05 to 1.06)	1.09 (1.08 to 1.09)
Point estimate at 80 y	1.00 (0.99 to 1.00)	0.95 (0.94 to 0.95)
Sex		
Female	1.08 (1.08 to 1.09)	1.01 (1.00 to 1.01)
Male	Referent	Referent
Cancer type		
Hematologic vs solid cancer (diagnosed in the last year)	1.20 (1.16 to 1.24)	1.37 (1.32 to 1.43)
Hematologic vs solid cancer (diagnosed 1-5 y prior)	1.09 (1.07 to 1.11)	1.22 (1.20 to 1.24)
Hematologic vs solid cancer (diagnosed 5-10 y prior)	1.03 (1.01 to 1.05)	1.12 (1.10 to 1.14)
Recent systemic therapy		
Recent systemic therapy vs none (diagnosed in last year)	1.02 (1.00 to 1.04)	1.01 (0.98 to 1.03)
Recent systemic therapy vs none (diagnosed 1-5 y prior)	1.00 (0.99 to 1.01)	1.07 (1.06 to 1.08)
Recent systemic therapy vs none (diagnosed 5-10 y prior)	1.12 (1.12 to 1.14)	1.11 (1.09 to 1.13)
Immigration status		
Recent	0.74 (0.72 to 0.76)	0.67 (0.65 to 0.70)
Nonrecent	0.80 (0.79 to 0.81)	0.71 (0.70 to 0.73)
Long-term resident/Canadian	Referent	Referent
Socioeconomic status		
Rural	0.87 (0.86 to 0.89)	0.88 (0.86 to 0.90)
Q1-low	0.82 (0.81 to 0.84)	0.86 (0.84 to 0.88)
Q2	0.87 (0.85 to 0.88)	0.89 (0.88 to 0.91)
Q3	0.90 (0.89 to 0.91)	0.91 (0.89 to 0.92)
Q4	0.94 (0.93 to 0.95)	0.93 (0.92 to 0.94)
Q5-high	Referent	Referent
Aggregated clinical groups		
0-4 ADGs	Referent	Referent
5-9 ADGs	1.36 (1.35 to 1.38)	1.06 (1.05 to 1.07)
10+ ADGs	1.30 (1.29 to 1.32)	1.04 (1.03 to 1.05)
Residential Instability quintile		
Q1- low	Referent	Referent
Q2	0.99 (0.98 to 1.00)	1.02 (1.00 to 1.03)
Q3	1.00 (0.99 to 1.01)	1.04 (1.03 to 1.06)
Q4	1.04 (1.02 to 1.05)	1.09 (1.07 to 1.11)
Q5- high	1.02 (1.00 to 1.03)	1.12 (1.10 to 1.14)
Material Deprivation quintile		
Q1-low	Referent	Referent
Q2	0.95 (0.94 to 0.96)	0.96 (0.95 to 0.97)
Q3	0.91 (0.90 to 0.92)	0.93 (0.92 to 0.95)
Q4	0.86 (0.85 to 0.88)	0.89 (0.87 to 0.90)
Q5-high	0.80 (0.78 to 0.81)	0.81 (0.80 to 0.83)
Dependency quintile		
Q1- low	Referent	Referent
Q2	1.04 (1.02 to 1.05)	1.02 (1.01 to 1.04)

(continued)

**Table 2.** (continued)

Variables	Full vaccination (n = 356 535) HR (95% CI)	Booster doses (n = 306 212) HR (95% CI)
Q3	1.05 (1.04 to 1.07)	1.04 (1.02 to 1.05)
Q4	1.07 (1.06 to 1.08)	1.05 (1.04 to 1.07)
Q5- high	1.13 (1.12 to 1.15)	1.07 (1.06 to 1.09)
Ethnic Concentration quintile		
Q1-low	Referent	Referent
Q2	1.00 (1.00 to 1.02)	1.02 (1.01 to 1.04)
Q3	1.01 (1.00 to 1.02)	1.03 (1.01 to 1.04)
Q4	1.03 (1.01 to 1.04)	1.01 (1.00 to 1.03)
Q5- high	1.00 (0.99 to 1.02)	0.97 (0.95 to 0.99)
Resident of a long-term care facility		
Yes	—	1.05 (1.02 to 1.09)
No	—	Referent
COVID-19 infection before first dose		
Yes	1.12 (1.10 to 1.15)	0.87 (0.84 to 0.90)
No	Referent	Referent
Regional Public Health Authority		
Central East	0.83 (0.81 to 0.84)	1.15 (1.13 to 1.18)
Central West	0.86 (0.85 to 0.87)	1.05 (1.04 to 1.07)
Durham	0.95 (0.93 to 0.97)	0.98 (0.95 to 1.00)
Eastern	0.83 (0.81 to 0.84)	1.22 (1.20 to 1.25)
North	0.90 (0.88 to 0.91)	1.08 (1.05 to 1.10)
Ottawa	0.93 (0.91 to 0.94)	1.28 (1.24 to 1.30)
Peel	0.93 (0.91 to 0.94)	0.85 (0.84 to 0.87)
South West	0.87 (0.86 to 0.88)	1.15 (1.13 to 1.17)
York	0.98 (0.97 to 1.00)	0.96 (0.94 to 0.98)
Toronto	Referent	Referent
Time to second dose		
Increment: week	—	1.07 (1.07 to 1.07)
Omicron		
After Omicron	—	1.05 (1.03 to 1.06)
Before Omicron	—	Referent

<sup>a</sup> HR = hazard ratio; CI = confidence interval; ADG = aggregated diagnosis groups.

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**Author contributions:** MP: conceptualization, writing-original draft, funding acquisition, formal analysis, project administration; RS: formal analysis, methodology, writing- review and editing; AP: data curation, formal analysis, visualization; MC: conceptualization, formal analysis, writing- review and editing, resources; IG: conceptualization, formal analysis, project administration, writing- review and editing; AV: conceptualization, formal analysis, writing-review and editing; LKH: conceptualization, formal analysis, writing- review and editing; DW: methodology, formal analysis, visualization, supervision; MKK: conceptualization, formal analysis, funding acquisition, resources, supervision, writing- review and editing; SS: conceptualization, formal

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## Data availability

The administrative data underlying this article were accessed from ICES. External researchers can access the dataset used in this analysis by requesting access through ICES Data and Analytic Services; details of this process and the required forms are available at: <https://www.ices.on.ca/DAS/Public-Sector/Access-to-ICES-Data-Process>.

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