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The impact of COVID-19 on Immigrants and Refugees living with Cancer: A Population-Based Cohort Study in Ontario, Canada

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Abstract

Background: While the COVID-19 pandemic has taken an enormous toll on communities across Canada, its negative impacts have not been experienced equally within immigrant and refugee communities. This disparity emanates from their systematically marginalized social and economic position in Canada. The association of social inequities with adverse COVID-19 outcomes can further be intensified in the context of underlying chronic health conditions like Cancer. There is a paucity of information on the impact of COVID-19 on immigrants living with active cancer. Our study aimed to address this gap.

Methods: A population-based retrospective cohort study over 2 years (March 31, 2020, to December 31, 2021) was conducted based on multiple linked provincial-administrative databases. Multivariable regression was utilized to assess the differential impact of COVID-19 on immigrants and non-immigrants with and without active cancer while adjusting for potential socioeconomic and health-related confounders (e.g., age, sex, income, comorbidities, and access to primary care).

Results: Our study comprised about 10.4 million Ontario residents aged 18 or older, of which 24% were identified as immigrants and 0.7% lived with an active cancer. Among immigrants with active cancer, 63% were female. A higher proportion of immigrants living with cancer, compared to non-immigrants with cancer, lived in neighbourhoods that had the lowest household income (26% vs 18%), were the most residentially unstable (29% vs 25%), were the most materially deprived (23% vs 17%,) and were the most ethnically diverse (59% vs. 17%). About 15% of immigrants with active cancer also suffered from mental health and addiction disorders. The prevalence of confirmed COVID-19 test results was significantly higher among immigrants than non-immigrants living with cancer. Furthermore, when we adjusted for covariates, immigrants living with active cancer were 3 times more likely to be hospitalized and be admitted to ICU, and 4 times more likely to die from COVID-19 than their peers.

Conclusion: Our study provides evidence that immigrants with active cancer were more socially and economically disadvantaged and had worse COVID-19 outcomes compared to their peers. System-level intervention is needed to protect those at the intersection of clinical and social vulnerabilities during pandemic recovery and in future crises.

Keywords: Immigrant; Refugee; COVID-19; Ethnic groups; Cancer; Health inequities; Ontario Marginalization index; Canada.

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Introduction

The COVID-19 pandemic has taken an enormous toll on individuals and communities across the globe, with more than 700 million confirmed cases and about 7 million deaths worldwide[1]. In Canada, over 4.7 million COVID-19 confirmed cases have been reported, and the virus has claimed a significant number of lives, with the death toll reaching 54,100 as of October 2023[2]. However, the distribution of COVID-19 cases, hospitalization and mortality was disproportionately higher among racialized immigrants and low-income populations[3-6]. Studies indicate that migrants in high-income countries, including Canada, face increased risks related to COVID-19 due to their social circumstances [6]. In Ontario, Canada's most populated province that has become home to approximately 250,000 immigrants annually, immigrants and refugees made up more than half of COVID-19 confirmed cases despite comprising only a quarter of the population[7]. These inequities are directly related to the social and economic conditions that immigrants are more likely to face, such as 1) living in multigenerational, overcrowded households, 2) working in precarious low-wage occupations and/or high-risk settings with no provision for paid sick leave, 3) working in jobs where working from home and obeying physical distancing policies is less likely which in turn increases the likelihood of direct exposure to COVID-19, 4) relying heavily on public transportation, and 5) having limited social support [8-12].

These social inequities compounded with underlying chronic health conditions like cancer may intensify susceptibility to COVID-19 and its sequelae. As the leading cause of death in Canada, cancer has long been a significant public health concern13. Although there is no Canadian-based information about the proportion of immigrants and refugees living with cancer it is estimated that approximately 43% of Canadians receive a cancer diagnosis in their lifetime. With an aging and growing population, the number of new cancer cases and deaths continues to rise [13]. Against this backdrop, the emergence of the novel coronavirus, SARS-CoV-2, and the resulting COVID-19 pandemic has introduced unprecedented challenges to the healthcare system, with particular ramifications for individuals living with cancer, including delays in investigations, diagnoses and treatment of cancer, and setbacks in cancer research. Cancers and their treatments can weaken patients' immune system, increasing their susceptibility to a COVID-19 infection and potential severe complications[14-16]. People living with cancer are at a clinical vulnerability in the context of the COVID-19 pandemic. Thus, immigrants and refugees living with cancer are at the intersection of social and clinical disadvantages in the context of COVID-19 infection and prognosis. However, there is no literature that examines compounding disadvantages and increased risk of COVID-19 for this group. Understanding the interaction between COVID-19, immigration, and cancer care is essential for developing targeted interventions and addressing health inequities during post-pandemic recovery as well as future crises. Thus, this population-based retrospective cohort study, aimed to explore the impact of COVID-19 on Ontario's immigrants and refugees (called "immigrants" hereafter) living with cancer. The specific objectives were:

1) To compare COVID-19-related outcomes (vaccination rates, diagnoses, hospitalizations, ICU admissions, and mortality) among immigrants with active cancers versus three comparison groups: immigrants without active cancer and non-immigrants with and without cancer.

2) To determine the role that sociodemographic and healthcare-related variables (e.g., sex, age, immigration status, region of origin, neighbourhood income quintile, neighbourhood marginalization index, access to primary care) play in COVID-19-related outcomes for immigrants with active cancers vs. comparison groups.

Methods

Study Design & Setting

We conducted a population-based retrospective cohort study using multiple linked Ontario healthcare administrative databases at ICES (previously known as the Institute for Clinical Evaluative Sciences). The two-year study period spanned from March 31, 2020, to December 31, 2021, and corresponded to COVID-19 waves 1-4 (February 26, 2020-December 14, 2021), and the first 16 days of wave 5 (December 15 -31, 2021).

Data Sources

The study cohort was created by linking the following provincial databases: Ontario Cancer Registry (OCR) which includes all Ontario residents who have been newly diagnosed with cancer (except for basal cell carcinoma and squamous cell carcinoma of the skin), and those who have died of cancer; the Immigration, Refugees and Citizenship Canada Permanent Resident database (IRCC) comprises demographic characteristics of landed immigrants and refugees in Canada since 1985; Canadian Institute for Health Information Discharge Abstract Database (CIHI DAD) contains detailed diagnostic and procedural information for all inpatient hospital admissions in Canada; National Ambulatory Care Reporting System (NACRS) captures information on patient visits to hospitals and community-based ambulatory care: day surgery, outpatient clinics and emergency departments; Same Day Surgery (CIHI SDS) contains patient-level data for day surgery institutions in Ontario. Every record corresponds to one same-day surgery or procedure stay; The Ontario Health Insurance Plan (OHIP) identifies physician billing claims and specialty on all services provided by fee-for-service physicians in Ontario; the Registered Persons Database (RPDB) contains the age,

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sex and postal code of all Ontario residents who are eligible for OHIP; the Ontario Drug Benefit (ODB) database contains claims for prescription drugs received under the Ontario Drug Benefit program as well as services provided to long-term care (LTC) residents. Primary Care Population (PCPOP) is an ICES-derived population-level dataset that includes all people in Ontario who are deemed alive and eligible for health insurance at a given point in time. The Client Agency Program Enrolment (CAPE) indicates the enrolment of an individual with a specific family physician and group in a formally recognized program, including primary care Patient Enrolment Models (PEM). The PEM structure is based on various models of primary care providers' compensation including incentives and bonuses which include: 1) Family Health Group [FHG] / Comprehensive Care Model [CCM]- Primarily an enhanced fee-for-service model,2) Family Health Team [FHT] –primarily a capitation-based model and using interprofessional teams, 3) Non-FHT (i.e. Family Health Organization (FHO) and Family Health Network (FHN)- primarily capitation-based, 4) Other PEM (e.g., Community Health Group, Group Health Center, Rural Northern Physician Group (RNPGA)), 5) Traditional fee-for-service (TFFS) (physicians who do not belong to any of the above-mentioned models), and 6) No Care[17-18]. The Ontario Marginalization Index (ON-Marg-2016) is a geographically (Census) based index developed to quantify the degree of marginalization occurring across the province of Ontario. It is comprised of 4 major dimensions thought to underlie the construct of marginalization: residential instability (i.e. family structure, ownership and occupancy), material deprivation (i.e. income, education, lone-parent families, housing quality), dependency (population workforce eligibility, proportion of population aged 65+ and less than 15) and ethnic concentration (recent immigrants and visible minorities)[19-20]. The index is determined using ecological linkages based on individuals' postal codes from the Postal Code Conversion File to the 2016 Canadian Census. The COVID-19 Integrated Testing Data (C19INTGR) is created by ICES, this is a comprehensive dataset of all available COVID-19 diagnostic lab results in Ontario, including those from Ontario Laboratories Information System (OLIS), distributed testing laboratories, Public Health CCM, and Ontario COVID-19 Vaccine Data (COVaxON) which includes information on COVID-19 vaccination events. All indicators are as of the index date (March 31, 2020), with various look-back periods. These datasets were linked using unique encoded identifiers and analyzed at ICES.

Study Population

The study cohort included all Ontario adult residents aged 18 or above who were alive on March 31, 2020, and were eligible for OHIP for the entire study period. Immigrants were defined based on inclusion in the IRCC database. Active cancer cases were defined as a cancer diagnosis at any time from OCR with cancer-related procedures within 6 months of the index date (i.e., March 31, 2020) OR a new cancer diagnosis as identified by OCR within 1 year of the index date. We excluded anyone living in a rural area, as most immigrants live in urban areas, and anyone residing in a long-term care facility as there was evidence the trajectory of COVID-19 infections was different in long-term facilities compared to the community. We then divided our study cohort into four groups: 1) immigrants with active cancer, 2) immigrants without active cancer, 3) non-immigrants with active cancer, and 4) non-immigrants without active cancer.

Study outcomes and variables

The primary outcome measure was COVID-19 diagnosis, which was defined as at least one positive lab result in OLIS at any point from March 31, 2020, to December 31, 2021. Secondary outcomes included hospitalizations, ICU admissions, and mortality due to COVID-19 and COVID-19 vaccinations. Hospitalizations and ICU admissions attributed to COVID-19 were defined as positive SARS-CoV-2 tests within 14 days prior to or 3 days after hospitalization. Similarly, we defined mortality due to COVID-19 as death within 30 days following a positive SARS-CoV-2 test or within 7 days post-mortem. Vaccination was defined as receiving at least one dose during the study period.

We also assessed individual and system-level covariates which included sociodemographic and clinical characteristics: age, sex, immigration category, years since landing in Canada, region of origin based on country of citizenship (East Asia & the Pacific, Europe & Central Asia, Latin America & the Caribbean, Middle East & North Africa, North America, South Asia, Sub-Saharan Africa, and Western Europe), region of residence in Ontario (Central East, Central South, Central West, East, North, Toronto, South West), neighbourhood income quintile (1 – lowest income to 5 – highest income), and Ontario Marginalization Index- with each dimension organized into quintiles (1- least deprived to quintile 5- the most deprived), whether the person had a primary care provider, primary care patient enrollment model (PEM), and number of comorbidities.

Ethical Review:

Ethics approval was obtained through ICES, an independent, not-for-profit corporation, that is a prescribed entity under section 45 of Ontario's Personal Health Information Protection Act (PHIPA). Section 45 authorizes ICES to collect personal health information, without consent, for the purpose of analysis or compiling statistical information with respect to the management of, evaluation or monitoring of, the allocation of resources to or planning for all or part of the health system. Projects conducted under section 45, by definition, do not require review by a Research Ethics Board. This project was conducted under section 45 and approved by ICES' Privacy and Legal Office. All methods were carried out in accordance with relevant guidelines and regulations.

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Analysis:

We utilized descriptive statistics, specifically means, medians and standard deviation (SD) for continuous variables and proportions for categorical variables to report baseline characteristics of the study population across 4 subgroups. For each variable standard differences (Std diff) between subgroups were obtained. A standard difference of >0.1 was considered as statistically significant in the distribution of the characteristics across subgroups. For each binary study outcome measure, we conducted logistic regression to assess the adjusted odds ratios (AORs) with 95% CI for immigrants with /without cancer and non-immigrants with cancer compared to the non-immigrants without cancer, after accounting for covariates. Based on findings from descriptive analyses, our regression model included covariates with Std diff >0.1 (i.e., age, sex, income quintile (this was included in place of Ontario Marginalization Index(ON Marg) as they were highly correlated), years since landing, region of residence in Ontario, primary care model, and the number of co-morbidities). Significance was set at $p < 0.05$.

Results

Our cohort (see Figure 1) comprised 10,356,878 Ontario residents aged 18 or older of which 2,496,963 (24.1%) were identified as immigrants, and 7,859,915 (75.9%) were identified as Canadian-born/long-term residents of Canada (referred to from here on as "non-immigrants").

Table 1 shows the sociodemographic and healthcare-related characteristics across all 4 study subgroups. Among immigrants, 16,248 (0.7%) were identified as having active cancer based on the study definition. Among non-immigrants, 93,564 (1.2%) were identified as having active cancer. The difference was not significant (std diff=0.057). Just under two-thirds of immigrants with active cancer were female as opposed to slightly more than half among non-immigrants with active cancer (63.3% vs, 55.8%, Std diff=0.154). A considerably higher proportion of immigrants with active cancer lived in low-income, residentially unstable, materially deprived, and ethnically diverse neighbourhoods than non-immigrants with active cancer (26% vs. 18%, Std diff= 0.206; 29% vs. 25%, Std diff=0.1; 23% vs, 17%, Std diff= 0.131, 59% vs. 17%, Std diff=0.938 respectively for Q1 (lowest-income quintile) vs. Q5 (the most deprived) for each of marginalization index variable). About 16% of immigrants with and without cancer were refugees and protected persons in Canada. Most immigrants with and without cancer were admitted to Canada under the Economy category (i.e. 44% vs 47% respectively) and Family category (38% vs.35% respectively). The average length of stay in Canada for immigrants with cancer was significantly longer than for immigrants without cancer (19.8 vs. 16.7, std diff=0.346). The most common region of origin for immigrants with active cancer was Europe and Central Asia (31.7%) followed by East Asia and Pacific (29.2%), South Asia (16.7%), Latin America and the Caribbean (13.7%), and Sub-Saharan Africa (7.0%). In contrast, for immigrants without cancer, the most common region of origin was East Asia and Pacific (26.2%), followed by South Asia, Europe and Central Asia, Latin America and the Caribbean, and Sub-Saharan Africa. A significantly higher proportion of immigrants without cancer (i.e. 9.3%) did not have a primary care provider compared to non-immigrants with or without cancer (i.e., 1.6% vs 7.4% respectively) and immigrants with cancer (i.e., 1.2%). The most common primary care model for immigrants with active cancer was FHG (primarily fee-for-service, 45.8%)

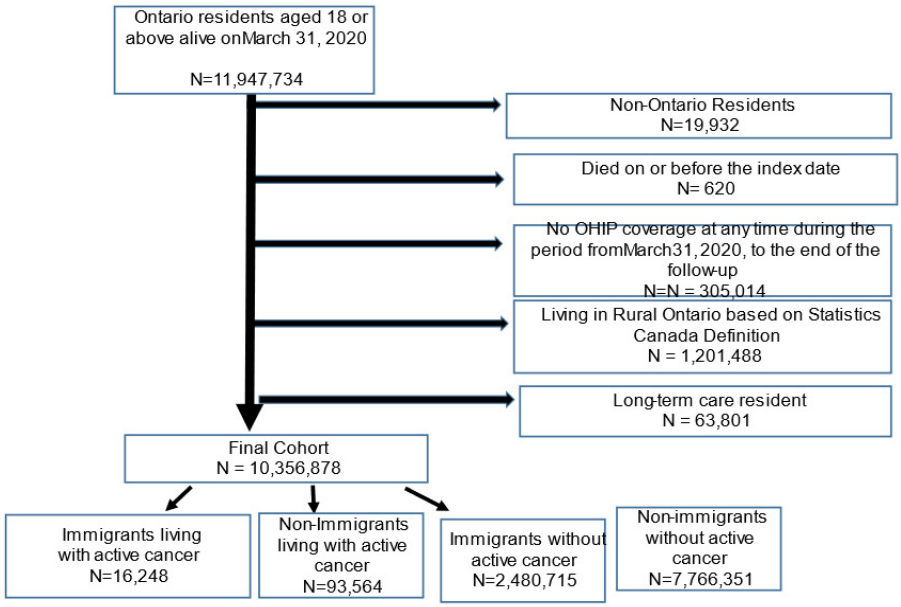

Figure 1: Study Cohort flow chart including immigrant and non-immigrant populations with and without cancer in Ontario, Canada

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vs. 37.5% of non-immigrants with cancer who were in a primarily capitation-based model. Virtual and in-person visits to all types of physicians were higher among immigrants and non-immigrants with active cancer than immigrants and non-immigrants without active cancer. Among those with cancer, immigrants were more likely to have a breast cancer diagnosis

COVID-19 Confirmed Positive Test

Confirmed positive test results were significantly higher among immigrants with cancer (12.4%) than non-immigrants with cancer (5.3%). Similarly, a significantly higher proportion of immigrants without cancer tested positive vs. non-immigrants without cancer (19.1% vs. 10.5%) (Figure 2).

COVID-19 Diagnosis

The prevalence of COVID-19 was significantly higher among immigrants with active cancer vs. both non-immigrant groups and was more than double that of non-immigrants with active cancer (7.4% vs.3.2%, Std diff=0.19). (Table 1).

COVID-19 Hospitalization

COVID-19 hospitalization was higher at 1.2% among immigrants living with cancer than all other comparison groups: 0.6% for non-immigrants living with cancer (Std diff=0.066), 0.3% for immigrants without cancer (Std diff=0.102), and 0.2% for non-immigrants without cancer (Std diff= 0.12) (Table 1).

Table 1: Sociodemographic and HealthCare-Related characteristics

	Group 1	Group 2	Group 3	Group 4	Standardized Difference			
Categories	**Immigrants and refugees living with Cancer N=16,248**	**Canadian-born /long-term residents living with Cancer N=93,564**	**Immigrants and refugees without Cancer N=2,480,715**	**Canadian-born/ long-term residents without Cancer N=7,766,351**	**Gr1 vs. Gr2**	**Gr1 vs. Gr3**	**Gr1 vs. Gr4**	**G2 vs. G4**
Age								
Mean (SD)	59.1 (13.9)	65.7 (14.6)	46.7 (15.8)	49.0 (19.0)	0.463	0.83	0.604	0.984
Median (Q1-Q3)	59 (50-69)	68 (58-76)	46 (35-57)	49 (32-64)	0.523	0.873	0.637	1.008
18-24 - n (%)	89 (0.5)	670 (0.7)	165,336 (6.7)	885,707(11.4)	0.021	0.075	0.471	0.46
25-44 - n (%)	2,377 (14.6)	8,156 (8.7)	1,018,702(41.1)	2,484,364(32.0)	0.185	0.013	0.42	0.604
45-64 - n (%)	7,956 (49.0)	29,395(31.4)	957,424(38.6)	2,571,968(33.1)	0.364	0.006	0.326	0.036
65-74 - n (%)	3,627 (22.3)	28,554(30.5)	205,734 8.3)	1,034,356(13.3)	0.187	0.003	0.237	0.425
75+ - n (%)	2,199 (13.5)	26,789(28.6)	133,519(5.4)	789,956 (10.2)	0.377	0.003	0.104	0.48
Sex								
Female - n (%)	10,290 (63.3)	52,183(55.8)	1,292,615(52.1)	3,966,559(51.1)	0.154	0.229	0.25	0.094
Male - n (%)	5,958 (36.7)	41,381(44.2)	1,188,100(47.9)	3,799,792 48.9)	0.154	0.229	0.25	0.094
Income quintile								
1 (lowest) - n (%)	4,225 (26.0)	16,426(17.6)	623,960 (25.2)	1,383,202(17.8)	0.206	0.02	0.199	0.007
2 - n (%)	3,518 (21.7)	18,576(19.9)	538,043 (21.7)	1,502,876(19.4)	0.044	0.001	0.057	0.013
3 - n (%)	3,194 (19.7)	18,611(19.9)	516,835 (20.8)	1,548,731(19.9)	0.006	0.029	0.007	0.001
4 - n (%)	2,990 (18.4)	18,665 19.9)	457,536 (18.4)	1,586,605(20.4)	0.039	0.001	0.051	0.012
5 (highest) - n (%) 5- n (%)	2,291 (14.1)	21,181(22.6)	340,137 (13.7)	1,730,347(22.3)	0.222	0.011	0.213	0.009
0 Missing information - n (%)	30 (0.2)	105 (0.1)	4,204 (0.2)	14,590 (0.2)	0.019	0.004	0.001	0.02
Residential instability quintile								
0 Missing information - n (%)	42 (0.3)	465 (0.5)	6,462 (0.3)	43,463 (0.6)	0.039	0	0.047	0.009
1 - n (%)	4,367 (26.9)	16,789 (17.9)	696,078 (28.1)	1,597,299(20.6)	0.215	0.026	0.149	0.067
2 - n (%)	2,573 (15.8)	17,428 (18.6)	392,881 (15.8)	1,437,879 18.5)	0.074	0	0.071	0.003

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3 - n (%)	2,147 (13.2)	17,211 (18.4)	343,495 (13.8)	1,359,131(17.5)	0.142	0.018	0.119	0.023
4 - n (%)	2,395 (14.7)	18,345 (19.6)	354,753 (14.3)	1,460,357(18.8)	0.129	0.012	0.109	0.02
5 - n (%)	4,724 (29.1)	23,326 (24.9)	687,046 (27.7)	1,868,222(24.1)	0.093	0.031	0.114	0.02
Deprivation quintile								
0 Missing information - n (%)	42 (0.3)	465 (0.5)	6,462 (0.3)	43,463 (0.6)	0.039	0	0.047	0.009
1 - n (%)	3,201 (19.7)	23,385 (25.0)	503,599 (20.3)	1,964,735(25.3)	0.127	0.015	0.134	0.007
2 - n (%)	3,170 (19.5)	19,586 (20.9)	488,361 (19.7)	1,648,944 21.2)	0.035	0.004	0.043	0.007
3 - n (%)	2,953 (18.2)	17,495 (18.7)	465,726 (18.8)	1,417,911(18.3)	0.014	0.015	0.002	0.011
4 - n (%)	3,227 (19.9)	16,463 (17.6)	479,119 (19.3)	1,324,076(17.0)	0.058	0.014	0.073	0.014
5 - n (%)	3,655 (22.5)	16,170 (17.3)	537,448 (21.7)	1,367,222(17.6)	0.131	0.02	0.122	0.008
Dependency quintile								
0 Missing information - n (%)	42 (0.3)	465 (0.5)	6,462 (0.3)	43,463 (0.6)	0.039	0	0.047	0.009
1 - n (%)	5,518 (34.0)	17,275(18.5)	981,810 (39.6)	1,966,795(25.3)	0.358	0.117	0.19	0.166
2 - n (%)	3,617 (22.3)	16,871(18.0)	558,547 (22.5)	1,578,267(20.3)	0.106	0.006	0.047	0.058
3 - n (%)	2,693 (16.6)	17,604 18.8)	377,098 (15.2)	1,424,609(18.3)	0.059	0.038	0.047	0.012
4 - n (%)	2,325 (14.3)	17,871(19.1)	319,369 (12.9)	1,345,928(17.3)	0.129	0.042	0.083	0.046
5 - n (%)	2,053 (12.6)	23,478(25.1)	237,429 (9.6)	1,407,289(18.1)	0.323	0.098	0.152	0.17
Ethnic Diversity Quintile								
0 Missing information - n (%)	42 (0.3)	465 (0.5)	6,462 (0.3)	43,463 (0.6)	0.039	0	0.047	0.009
1 - n (%)	376 (2.3)	15,894(17.0)	49,646 (2.0)	1,060,283(13.7)	0.513	0.022	0.428	0.093
2 - n (%)	846 (5.2)	20,106(21.5)	114,021 (4.6)	1,466,775(18.9)	0.493	0.028	0.43	0.065
3 - n (%)	1,707 (10.5)	20,804(22.2)	245,242 (9.9)	1,692,645(21.8)	0.321	0.02	0.31	0.011
4 - n (%)	3,756 (23.1)	20,037(21.4)	568,344 (22.9)	1,809,011(23.3)	0.041	0.005	0.004	0.045
5 - n (%)	9,521 (58.6)	16,258(17.4)	1,497,000(60.3)	1,694,174(21.8)	0.938	0.036	0.809	0.112
Ontario, Regions								
Missing Data - n (%)	37 (0.2)	212 (0.2)	5,590 (0.2)	22,716 (0.3)	0	0.001	0.013	0.013
Central East - n (%)	3,530 (21.7)	18,443(19.7)	496,011 (20.0)	1,515,767(19.5)	0.05	0.043	0.055	0.005
Central South - n (%)	899 (5.5)	11,950(12.8)	118,357 (4.8)	887,011 (11.4)	0.253	0.034	0.213	0.041
Central West - n (%)	4,124 (25.4)	16,212 17.3)	730,601 (29.5)	1,512,963(19.5)	0.197	0.091	0.142	0.056
East - n (%)	878 (5.4)	12,990(13.9)	153,999 (6.2)	1,077,389(13.9)	0.29	0.034	0.29	0
North - n (%)	59 (0.4)	5,468 (5.8)	10,462 (0.4)	412,347 (5.3)	0.32	0.009	0.301	0.023
Southwest - n (%)	713 (4.4)	11,776(12.6)	120,031 (4.8)	899,973 (11.6)	0.297	0.021	0.268	0.031
Toronto - n (%)	6,008 (37.0)	16,513(17.6)	845,664 (34.1)	1,438,185(18.5)	0.444	0.06	0.421	0.023
Primary Care Provider								
0 - n (%)	193 (1.2)	1,512 (1.6)	231,613 (9.3)	578,047 (7.4)	0.036	0.371	0.312	0.283
1 - n (%)	16,055 (98.8)	92,052 98.4)	2,249,102(90.7)	7,188,304(92.6)	0.036	0.371	0.312	0.283

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Enrollment model - Physician/ Patient								
Capitation (Family Health Network or Family Health Organization) - n (%)	4,599 (28.3)	35,112 37.5)	588,479 (23.7)	2,589,250(33.3)	0.197	0.105	0.109	0.088
Comprehensive Care model - n (%)	934 (5.7)	2,618 (2.8)	137,867 (5.6)	224,521 (2.9)	0.146	0.008	0.141	0.006
Family Health group - n (%)	7,436 (45.8)	20,356(21.8)	1,120,773(45.2)	1,880,679(24.2)	0.525	0.012	0.464	0.058
Family Health team - n (%)	1,990 (12.2)	28,864(30.8)	238,800 (9.6)	2,020,786(26.0)	0.464	0.084	0.356	0.107
Physician not in PEM - n (%)	1,077 (6.6)	4,291 (4.6)	162,573 (6.6)	422,330 (5.4)	0.089	0.003	0.05	0.039
No physician^ - n (%)	192 (1.2)	1,508 (1.6)	228,951 (9.2)	573,578 (7.4)	0.037	0.368	0.31	0.281
OGP (Other Enrollment group) - n (%)	20 (0.1)	815 (0.9)	3,272 (0.1)	55,207 (0.7)	0.107	0.002	0.091	0.018
Immigrant Category								
Missing Data - n (%)		93,564(100.0)		7,766,351(100.0)	.		.	.
Category not stated - n (%)	0 (0.0)		17 (0.0)			0.004		
Economic (Economic class) immigrants - n (%)	7,094 (43.7)	0 (0.0)	1,167,652(47.1)	0 (0.0)	1.245	0.069	1.245	
Other immigrants - n (%)	342 (2.1)	0 (0.0)	40,669 (1.6)	0 (0.0)	0.207	0.034	0.207	
Resettled Refugee & Protected Person in Canada - n (%)	2,632 (16.2)	0 (0.0)	406,201 (16.4)	0 (0.0)	0.622	0.005	0.622	
Sponsored family (Family Class) immigrants - n (%)	6,180 (38.0)	0 (0.0)	866,176 (34.9)	0 (0.0)	1.108	0.065	1.108	
Time since landing (years)								
Mean (SD)	19.8 (9.2)	*NA	16.7 (9.1)	*NA	.	0.346	.	.
Median (Q1-Q3)	21 (13-28)	*NA	17 (9-24)	*NA	.	0.345	.	
Region of Origin among immigrants - World Bank region								
Missing Data - n (%)		93,564(100.0)		7,766,351(100.0)	.		.	.
East Asia and Pacific - n (%)	4,741 (29.2)	0 (0.0)	650,152 (26.2)	0 (0.0)	0.908	0.066	0.908	
Europe and Central Asia - n (%)	5,149 (31.7)	0 (0.0)	630,490 (25.4)	0 (0.0)	0.963	0.139	0.963	

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Latin America and the Caribbean - n (%)	2,197 (13.5)	0 (0.0)	319,973 (12.9)	0 (0.0)	0.559	0.018	0.559	
North America - n (%)	*305-309	0 (0.0)	*45066-45070	0 (0.0)	0.197	0.006	0.197	
Not stated - n (%)	*1-5	0 (0.0)	*529-533	0 (0.0)	0.011	0.013	0.011	
South Asia - n (%)	2,712 (16.7)	0 (0.0)	647,096 (26.1)	0 (0.0)	0.633	0.231	0.633	
Sub-Saharan Africa - n (%)	1,139 (7.0)	0 (0.0)	187,405 (7.6)	0 (0.0)	0.388	0.021	0.388	
Type of Cancer as per study definition								
Missing Data - n (%)	0 (0.0)		24,80,715	7,766,351 (100.0)		.	.	.
			-100					
Breast - n (%)	4,454 (27.4)	18,993(20.3)	0 (0.0)	0 (0.0)	0.167	0.869	0.869	0.714
Cervix - n (%)	1,154 (7.1)	5,643 (6.0)	0 (0.0)	0 (0.0)	0.043	0.391	0.391	0.358
Colorectal - n (%)	1,350 (8.3)	8,720 (9.3)	0 (0.0)	0 (0.0)	0.036	0.426	0.426	0.453
Hematologic - n (%)	1,554 (9.6)	9,965 (10.7)	0 (0.0)	0 (0.0)	0.036	0.46	0.46	0.488
Lung - n (%)	924 (5.7)	7,231 (7.7)	0 (0.0)	0 (0.0)	0.082	0.347	0.347	0.409
Other - n (%)	5,358 (33.0)	32,231 (34.4)	0 (0.0)	0 (0.0)	0.031	0.992	0.992	1.025
Prostate - n (%)	1,454 (8.9)	10,781 (11.5)	0 (0.0)	0 (0.0)	0.085	0.443	0.443	0.51
Number of Aggregated Diagnosis Groups (ADGs), i.e., comorbidities *								
0-1 - n (%)	6,604 (40.6)	23,669 (25.3)	15,27,946	3,516,779 (45.3)	0.331	0.429	0.094	0.428
			-61.6					
2 - n (%)	3,425 (21.1)	18,482 (19.8)	412,825 (16.6)	1,541,208 (19.8)	0.033	0.114	0.031	0.002
3 - n (%)	2,636 (16.2)	17,660 (18.9)	253,495 (10.2)	1,092,878 (14.1)	0.07	0.178	0.06	0.13
4 - n (%)	1,663 (10.2)	13,526 (14.5)	144,275 (5.8)	699,908 (9.0)	0.129	0.163	0.041	0.17
5+ - n (%)	1,920 (11.8)	20,227 (21.6)	142,174 (5.7)	915,578 (11.8)	0.265	0.216	0.001	0.266
Aggregated Diagnosis Groups (ADGs), i.e., comorbidities								
Mean (SD)	2.2 (1.8)	3.0 (2.0)	1.5 (1.6)	2.1 (1.9)	0.401	0.444	0.054	0.444
Median (Q1-Q3)	2 (1-3)	3 (1-4)	1 (0-2)	2 (1-3)	0.408	0.486	0.083	0.491
Rate of visits to the physicians per 100 persons								
All physician in-person visits	12.6	12.5	4.1	4.3	-	-	-	-
All physician virtual visits	13.6	12.3	5.4	5.3	-	-	-	-
COVID-19 Diagnosis								
0 - n (%)	15,046 (92.6)	90,584 (96.8)	2,281,299 (92.0)	7,393,707 (95.2)	0.189	0.024	0.109	0.082

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1 - n (%)	1,202 (7.4)	2,980 (3.2)	199,416 (8.0)	372,644 (4.8)	0.189	0.024	0.109	0.082
COVID-19 Vaccination								
0 - n (%)	3,149 (19.4)	16,714 (17.9)	476,965 (19.2)	1,127,942 (14.5)	0.039	0.004	0.13	0.091
1 - n (%)	13,099 (80.6)	76,850 (82.1)	2,003,750 (80.8)	6,638,409 (85.5)	0.039	0.004	0.13	0.091
COVID -19 Hospitalization								
0 - n (%)	16,049 (98.8)	93,007 (99.4)	2,472,488 (99.7)	7,750,208 (99.8)	0.066	0.102	0.121	0.061
1 - n (%)	199 (1.2)	557 (0.6)	8,227 (0.3)	16,143 (0.2)	0.066	0.102	0.121	0.061
COVID-19 ICU Admission								
0 - n (%)	16,209 (99.8)	93,440 (99.9)	2,478,616 (99.9)	7,762,519 (100.0)	0.025	0.039	0.05	0.028
1 - n (%)	39 (0.2)	124 (0.1)	2,099 (0.1)	3,832 (0.0)	0.025	0.039	0.05	0.028
COVID-19 Mortality								
0 - n (%)	16,168 (99.5)	93,293 (99.7)	2,479,122 (99.9)	7,761,297 (99.9)	0.032	0.081	0.081	0.053
1 - n (%)	80 (0.5)	271 (0.3)	1,593 (0.1)	5,054 (0.1)	0.032	0.081	0.081	0.053

* - * * - Excluding cancer as a category among Immigrants/Non-Immigrants with Cancer

^ - Patient had no core primary care fee codes for 2 years prior to index

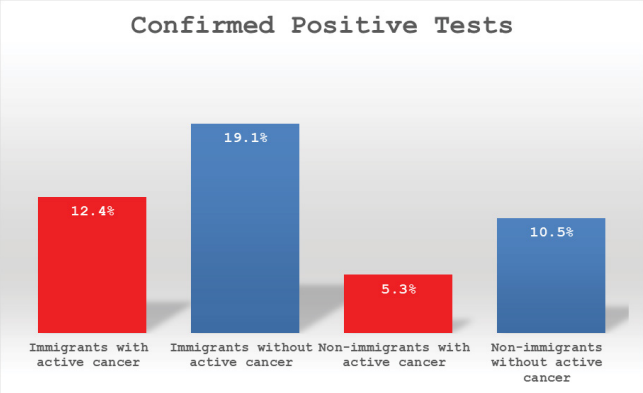

Figure 2: Percent positivity among those tested by immigration and active cancer status

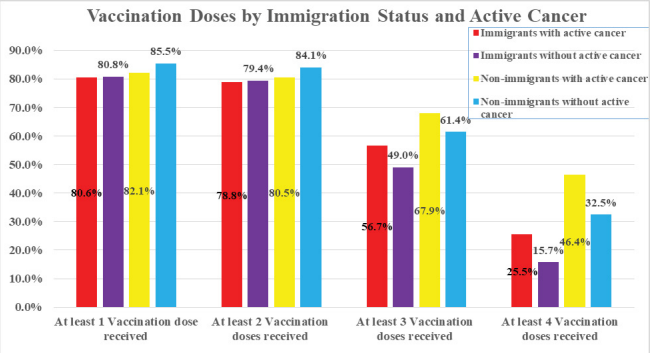

Figure 3: Vaccine data distribution by immigration and active cancer status

COVID-19 ICU Admission and Mortality

No significant differences in COVID-19 ICU admission and mortality crude rates were observed across immigrants and non-immigrants with or without active cancer.

COVID-19 Vaccinations

Immigrants with or without cancer were less likely to receive COVID-19 vaccines than non-immigrants with or without cancer. The proportion of people vaccinated across all four groups decreased as the number of doses increased (Figure 3). Only 25.5% of immigrants with cancer received at least 4 vaccine doses vs. 46.4% of non-immigrants with cancer.

Multivariate Analysis of COVID-19 Outcome Measures:

Table 2 shows our multivariate logistic regression as related to COVID-19 diagnosis. After adjusting for other variables in the model, *immigrants living with and without cancer were* 66% and 67% more likely to be diagnosed with COVID-19 than non-immigrants without cancer, while non-immigrants with cancer were 20% less likely. The prevalence of COVID-19 diagnoses was inversely related to neighbourhood income. Those living in the *lowest-income neighbourhoods were 23% more likely to be diagnosed with COVID-19* compared to the highest-income neighbourhoods. Immigrants *from Latin America and the Caribbean* were 16% more likely to be diagnosed with COVID-19 compared to individuals from Canada. The likelihood of COVID-19

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diagnosis increased with increasing number of comorbidities. *Patients without primary care providers* were 32% less likely to be diagnosed with COVID-19 compared to those enrolled in a Family Health Team. In other regions of Ontario, people were 60% to 20% less likely to be diagnosed with COVID-19 than in the Toronto region.

Figure 4 shows the final regression model as relates to COVID-19 hospitalization. Immigrants living with cancer were almost 3.3 times more likely to be hospitalized, and non-immigrants with cancer were 28% more likely to be hospitalized, than non-immigrants without cancer. Furthermore, immigrants without cancer were 97% more likely to be hospitalized than non-immigrants without cancer.

Table 2: Logistic regression results by Immigrant status and Cancer - COVID-19 Diagnosis.

Variables	Odds Ratios (95% confidence interval)
Immigration status (Non-immigrant without active cancer as the reference group)	
Immigrants with active cancer	**1.66 (1.56, 1.77)**
Immigrants without active cancer	**1.67 (1.64, 1.7)**
Non-immigrants with active cancer	0.80 (0.77, 0.83)
Age (1-year increase)	0.98 (0.98, 0.98)
Female (vs. Male)	0.93 (0.92, 0.93)
Neighbourhood income quintile (quintile 5 as the reference group)	
Income quintile 1 (lowest)	**1.23 (1.22, 1.24)**
Income quintile 2	1.16 (1.15, 1.17)
Income quintile 3	1.18 (1.17, 1.19)
Income quintile 4	1.11 (1.1, 1.12)
Missing *	1.11 (1.03, 1.2)
Region of origin (Canada as the reference group)	
East Asia and the Pacific	0.66 (0.65, 0.68)
Europe and Central Asia	0.84 (0.82, 0.86)
Latin America and the Caribbean	**1.16 (1.14, 1.18)**
North America	0.55 (0.52, 0.57)
South Asia	0.98 (0.96, 0.99)
Not stated *	1.22 (0.92, 1.62)
Length of OHIP eligibility time in Ontario (At least 20 years as the reference group)	
Less than 3 years	1 (0.99, 1.02)
At least 3 or 5 years	0.96 (0.95, 0.97)
At least 10 years	0.96 (0.95, 0.97)
Region of residence in Ontario (Toronto region as the reference group)	
Central East	0.79 (0.78, 0.79)
Central South	0.8 (0.79, 0.81)
Central West	0.91 (0.9, 0.92)
East	0.55 (0.55, 0.56)
North	0.4 (0.39, 0.41)
South West	0.69 (0.68, 0.69)
Missing *	0.8 (0.75, 0.85)
Co-morbidities (0-2 ADG as the reference group)	
3-4 ADGs	1.36 (1.35, 1.37)
5-6 ADGs	1.53 (1.51, 1.54)
7+	1.78 (1.76, 1.79)
Patient Enrollment Model (Family Health Team (FHT)- primarily capitation-based team model as the reference group)	
Family Health Groups (FHG)/ Comprehensive Care Model (CCM)	**1.24 (1.23, 1.25)**
Family Health Networks (FHN)/Family Health Organization (FHO)	**1.08 (1.07, 1.09)**
Physicians not in PEM	**1.22 (1.2, 1.23)**
Having no primary care physician	0.68 (0.67, 0.69)
Other	0.95 (0.9, 0.99)

The prevalence of COVID-19 hospitalization was inversely related to neighbourhood income. Those living in the lowest-income neighbourhoods were about 2.5 times more likely to be hospitalized compared to the highest-income neighbourhoods. The likelihood of COVID-19 hospitalization increased with increasing number of comorbidities. Those with 7 or more comorbidities were almost 3 times more likely to be hospitalized than those with no or 1-2 comorbidities. Patients without primary care providers were 11% more likely to be hospitalized compared to those enrolled in Family Health Teams. COVID-19 hospitalizations across other regions of Ontario were 66% to 26% less than in the Toronto region.

Table 3 shows the final regression model as relates to COVID-19 ICU Admission. Immigrants living with cancer were almost 3 times more likely to be admitted to ICU compared to non-immigrants without cancer, while non-immigrants with cancer were 25% more likely to be admitted to ICU. Immigrants without cancer were about twice more likely to be admitted to the ICU than non-immigrants without cancer. The prevalence of ICU admission was again inversely related to neighbourhood income. Those living in the lowest-income neighbourhoods were about 2.5 times more likely to be admitted to ICU compared to the highest-income neighbourhoods. Similar to hospitalization, ICU admission increased with the increasing number of comorbidities and patients without primary care providers were 20% more likely to be admitted to the ICU compared to those enrolled in the Family health team model. ICU admissions were 58% to 23% less across other regions in Ontario compared to Toronto.

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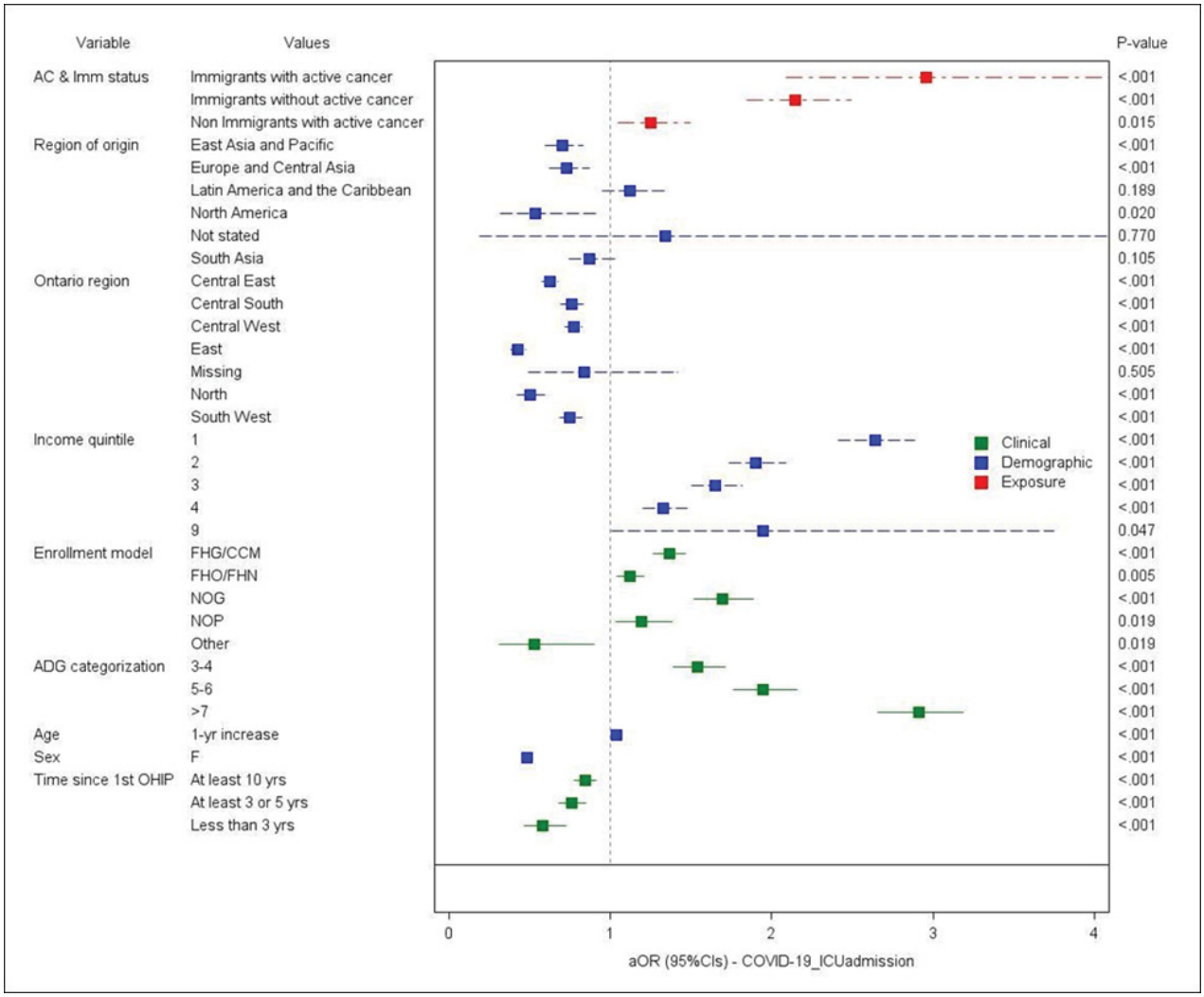

Figure 4: Logistic regression results by Immigrant status and Cancer - COVID-19 ICU Admission

Figure 5 shows the final regression model as relates to COVID-19 Mortality. The COVID-19 mortality among immigrants living with cancer was almost 4.2 times more than non-immigrants without cancer while COVID-19 mortality among both immigrants without cancer and non-immigrants with cancer was 56% more than non-immigrants without cancer. Immigrants from Latin America and the Caribbean were 33% more likely to die from COVID-19 compared to those from Canada. Those living in the lowest-income neighbourhoods were about 2.5 times more likely to die from COVID-19 compared to the highest-income neighbourhoods, and those with 7 or more comorbidities were about 3.6 times more likely to die from COVID-19 than those with no or 1-2 comorbidities. Patients with physicians who were not enrolled in PEM were 76% more likely to die from COVID-19 than those enrolled in the family health team. COVID-19 mortality was 63% to 22% less in other regions in Ontario compared to the Toronto region.

Table 4 shows the final regression model as relates to the uptake of COVID-19 Vaccination. COVID-19 vaccination among immigrants living with cancer was 48% less than non-immigrants without cancer while COVID-19 vaccination among non-immigrants with cancer was 55% less than non-immigrants without cancer. Immigrants from South Asia and from East Asia and the Pacific were more likely to receive COVID-19 vaccination compared to individuals from Canada, while all other immigrant groups were less likely. Those living in the lowest-income neighbourhoods were about 38% less likely to receive COVID-19 compared to the highest-income neighbourhoods. COVID-19 vaccination increased with increasing number of comorbidities; those with 7 or more comorbidities were about 2.8 times more likely to receive COVID-19 vaccination than those with no or 1-2 comorbidities. Patients without primary care providers were 78% less likely to undergo vaccination than those enrolled in the family health team. The uptake of COVID-19 vaccination was more likely in the East and North regions of Ontario (25% and 12% respectively) compared to the Toronto region.

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Table 3: Logistic regression results by immigrant status and Cancer - COVID-19 ICU Admission.

	Odds Ratios [95% confidence interval]
Immigration status (Non-immigrant without active cancer as the reference group)	
Immigrants with active cancer	**2.95 (2.09, 4.18)**
Immigrants without active cancer	**2.14 (1.84, 2.5)**
Non-immigrants with active cancer	**1.25 (1.04, 1.5)**
Age (1-year increase)	1.04 (1.03, 1.04)
Female (vs. Male)	0.48 (0.46, 0.51)
Neighbourhood income quintile (quintile 5 as the reference group)	
Income quintile 1 (lowest)	**2.64 (2.41, 2.89)**
Income quintile 2	1.9 (1.73, 2.09)
Income quintile 3	1.65 (1.5, 1.82)
Income quintile 4	1.33 (1.2, 1.47)
Missing *	1.94 (1.01, 3.75)
Region of origin (Canada as the reference group)	
East Asia and the Pacific	0.7 (0.59, 0.83)
Europe and Central Asia	0.73 (0.62, 0.87)
Latin America and the Caribbean	**1.12 (0.94, 1.34)**
North America	0.53 (0.32, 0.91)
South Asia	0.87 (0.74, 1.03)
Not stated *	1.34 (0.19, 9.62)
Length of OHIP eligibility time in Ontario (At least 20 years as the reference group)	
Less than 3 years	0.58 (0.46, 0.73)
At least 3 or 5 years	0.76 (0.68, 0.85)
At least 10 years	0.84 (0.77, 0.92)
Region of residence in Ontario (Toronto region as the reference group)	
Central East	0.62 (0.58, 0.68)
Central South	0.76 (0.69, 0.83)
Central West	0.77 (0.72, 0.83)
East	0.42 (0.38, 0.47)
North	0.5 (0.42, 0.59)
Southwest	0.75 (0.68, 0.82)
Missing *	0.84 (0.49, 1.42)
Co-morbidities (0-2 ADG as the reference group)	
3-4 ADGs	1.54 (1.39, 1.71)
5-6 ADGs	1.95 (1.76, 2.16)
7+	2.91 (2.65, 3.19)
Patient Enrollment Model (Family Health Team (FHT)- primarily capitation-based team model as the reference group)	
Family Health Groups (FHG)/ Comprehensive Care Model (CCM)	1.36 (1.26, 1.47)
Family Health Networks (FHN)/Family Health Organization (FHO)	1.12 (1.04, 1.21)
Physicians not in PEM	1.69 (1.52, 1.89)
Having no primary care physician	1.2 (1.03, 1.39)
Other	0.53 (0.31, 0.9)

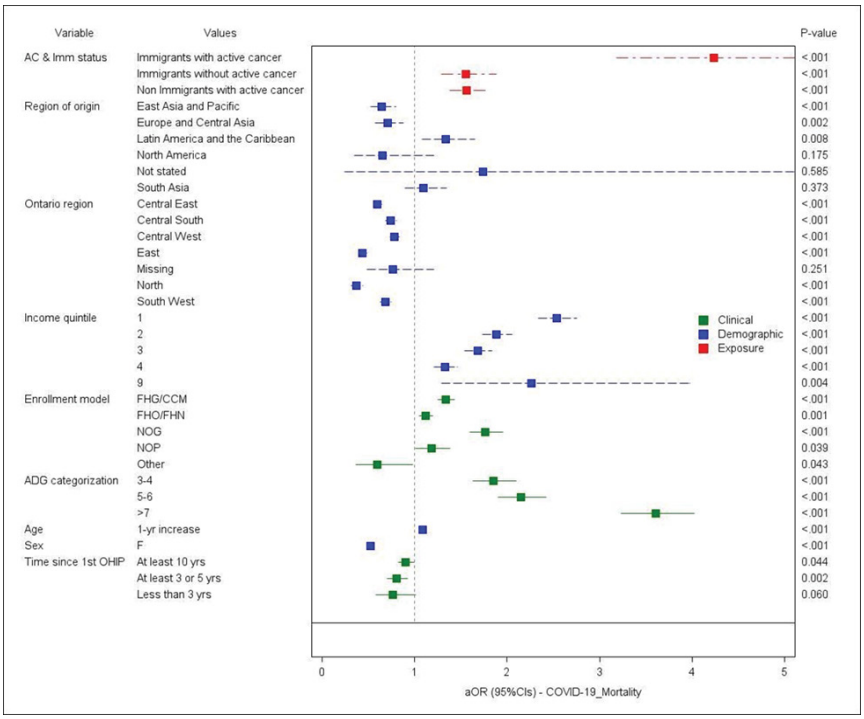

Figure 5: Logistic regression results by Immigrant status and Cancer - COVID-19 Mortality.

Citation: Vahabi M, Matai L, Damba C, Kopp A, Wong J, Rayner J, Narushima M, Tharao W, Hawa R, Janczur A, Datta G, Fung K, Lofters A. The impact of COVID-19 on Immigrants and Refugees living with Cancer: A Population-Based Cohort Study in Ontario, Canada. Journal of Environmental Science and Public Health. 8 (2024): 116-132.

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Table 4: Logistic regression results by immigrant status and Cancer - COVID-19 Vaccination

Variables	Odds Ratios [95% confidence interval]
Immigration status (Non-immigrant without active cancer as the reference group)	
Immigrants with active cancer	**0.52 (0.5, 0.55)**
Immigrants without active cancer	**0.89 (0.88, 0.9)**
Non-immigrants with active cancer	**0.45 (0.45, 0.46)**
Age (1-year increase	1 (1, 1)
Female (vs. Male)	0.94 (0.94, 0.95)
Neighbourhood income quintile (quintile 5 as the reference group)	
Income quintile 1 (lowest)	**0.62 (0.62, 0.63)**
Income quintile 2	0.74 (0.74, 0.75)
Income quintile 3	0.82 (0.82, 0.82)
Income quintile 4	0.91 (0.9, 0.91)
Missing *	0.66 (0.63, 0.69)
Region of origin (Canada as the reference group)	
East Asia and the Pacific	**1.43 (1.41, 1.45)**
Europe and Central Asia	0.64 (0.64, 0.65)
Latin America and the Caribbean	0.88 (0.87, 0.89)
North America	0.63 (0.61, 0.64)
South Asia	**1.53 (1.51, 1.55)**
Not stated *	0.8 (0.64, 1)
Length of OHIP eligibility time in Ontario (At least 20 years as the reference group)	
Less than 3 years	1.4 (1.39, 1.42)
At least 3 or 5 years	0.82 (0.82, 0.83)
At least 10 years	0.73 (0.72, 0.73)
Region of residence in Ontario (Toronto region as the reference group)	
Central East	1 (0.99, 1)
Central South	0.91 (0.9, 0.91)
Central West	1 (0.99, 1)
East	1.25 (1.24, 1.26)
North	1.12 (1.11, 1.13)
Southwest	0.93 (0.92, 0.94)
Missing *	0.67 (0.64, 0.69)
Co-morbidities (0-2 ADG as the reference group)	
3-4 ADGs	2.38 (2.37, 2.4)
5-6 ADGs	2.73 (2.71, 2.75)
7+	**2.84 (2.82, 2.85)**
Patient Enrollment Model (Family Health Team (FHT)- primarily capitation-based team model as the reference group)	
Family Health Groups (FHG)/ Comprehensive Care Model (CCM)	0.79 (0.79, 0.79)
Family Health Networks (FHN)/Family Health Organization (FHO)	0.93 (0.93, 0.94)
Physicians not in PEM	0.69 (0.68, 0.7)
Having no primary care physician	**0.22** (0.22, 0.22)
Other	1.01 (0.98, 1.04)

Discussion

In this population-based retrospective cohort study exploring the impact of COVID-19 on immigrants and refugees living with cancer in Ontario, Canada, we demonstrated that the combination of immigration status and active cancers played a significant role in the differential impact of COVID-19 outcome measures when controlling for other social and clinical confounding factors such as age, sex, income, region of origin, length of OHIP eligibility, and comorbidities. Overall, immigrants were significantly more likely to be diagnosed with COVID-19, be hospitalized, be admitted to ICU and die from COVID-19, and less likely to have received COVID-19 vaccination as compared to non-immigrants. A higher proportion of immigrants compared to non-immigrants had no access to primary care providers and lived in neighbourhoods characterized as low-income, residentially unstable, materially deprived, and ethnically diverse. The impact of COVID-19 was even worse among the 0.7% of immigrants and refugees who lived with active cancer, with this group having several orders of magnitude increased risk of COVID-19-related outcomes as compared to the non-immigrants without cancers in our logistic regression models. We also found a clear income gradient related to COVID-19 outcomes, and that patients of Family Health Teams appeared to be protected against COVID-19 outcomes.

These findings are in line with other studies that point to structural factors associated with the living and working conditions of immigrants which impede their ability to follow or access COVID-19 basic prevention and mitigation measures such as self-isolation, social distancing or accessing masks [2-13],[21-25]. Immigrants are disproportionately represented in precarious, low-paid jobs and sectors (e.g., agriculture, construction work, food services, retail/domestic work, and health-care provision) which require continuation of work and face-to-face interactions despite “social distancing” and “stay-at-home” recommendations [25]. Furthermore, living in multigenerational overcrowded housing where self-isolation of confirmed cases may be unrealistic and reliance on public transportation increases the risk of COVID-19 transmission, infection and severe health outcomes in this population [5-13,20,25] . Our findings suggest that a cancer diagnosis, despite increased vulnerability and increased connection to the healthcare system, does not protect against these ongoing social and structural barriers.

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Our study is the first study to examine the impact of COVID-19 on immigrants and refugees living with active cancer. Current evidence on cancer patients only suggests cancer enhances susceptibility to COVID-19 due to the immunosuppressed status resultant of cancer treatments and is a risk factor for severe clinical outcomes [14-16] [26-31]. In our study, the prevalence of COVID-19 was significantly higher among immigrants than non-immigrants living with cancer. Even though 60% of immigrants and non-immigrants with active cancers were tested for COVID-19, confirmed positive test results were twice more common among immigrants than non-immigrants. Furthermore, when we adjusted for covariates, immigrants living with active cancer were more likely to be hospitalized, be admitted to ICU, and die from COVID-19 than non-immigrants with and without cancer and immigrants without cancer. Our findings are in line with studies that reported higher hospitalization, ICU admission and mortality among cancer patients and socially vulnerable population groups [20-25] [32-34].

Our findings are novel and extend previous literature by revealing a disproportionately higher risk of severe or fatal COVID-19 among people who are at the intersection of social and clinical vulnerability (i.e., immigrants and refugees living with cancer). Immigrants with underlying chronic health conditions like cancer, may lack the ability to self-isolate or keep social distance from other confirmed cases in the household. Our results show access to social and economic resources is imperative in responding to and recovering from crises. The privilege of social distancing or staying at home translates to no income for most equity-seeking and equity-deserving groups including immigrants. The results clearly show the failure of systemic public administration to address the structural inequities that existed prior to and during COVID-19 and continue to persist if upstream interventions and policy initiatives like ensuring access to affordable housing, employment, education and health care are not in place.

We also found that COVID-19 vaccination uptake dropped dramatically after receiving the first dose across all our 4 cohorts. However, the drop was significantly larger among immigrants with or without cancer compared to non-immigrants with or without cancer. Language barriers, mistrust, disinformation, vaccination fatigue and/or low health literacy may all be contributing factors to the low uptake of vaccination. Research shows that limited fluency in official languages impedes immigrants' ability to access and understand public health information which consequently delays care and reduces the quality of care they receive [35-37]. The stark drop in vaccination may also be related to vaccine hesitancy around safety concerns, side effects, vaccine effectiveness, mistrust of government and medical organizations and experience of racial discrimination [38-42]. The vaccination drop among cancer patients may also be explained by accumulating evidence suggesting that anticancer therapy can impair the immune response to COVID-19 vaccination [43-44]. Hence, it is suggested that cancer patients consult their physicians about the timing and frequency of vaccination that should be administered during the period without active treatment.

We also found higher COVID-19 prevalence and adverse outcomes and lower vaccination uptake in the Toronto region which may be related to having a high proportion of immigrants.

The importance of primary care providers in the uptake of COVID-19 vaccination and diagnosis has been clearly illustrated in our study. Patients without primary care providers or seeing family physicians who are paid strictly fee-for-service were less likely to undergo vaccination and more likely to have poor COVID-19-related outcomes. This suggests that proactive approaches to connecting people to primary care, including interprofessional team-based care, should be prioritized by health systems, with a focus on people experiencing social and/or clinical disadvantage. Moreover, the results observed underscore the need for more targeted culturally specific outreach, education and care such as community ambassadors/champions, and mobile clinics, to reach vulnerable populations in high-needs areas.

Our study showed a higher proportion of breast cancer among immigrants than non-immigrants and immigrants with breast cancer were younger than non-immigrants with cancer. This may be related to the underutilization of breast cancer screening by immigrant women in Ontario. Prior to the COVID-19 pandemic, Canadian and international studies reported breast cancer screening underutilization among socially vulnerable populations including immigrants and refugees [45-51]. This makes a compelling argument to enhance access to cancer screening for socially vulnerable populations through evidence-based strategies like the use of community champions and peers to engage and educate under and never-screened women [52].

Limitations

To our knowledge, this is the first population-based study that examines the impact of COVID-19 on immigrants and refugees living with active cancer and non-immigrants with or without active cancer in Ontario, Canada. This is the unique contribution of our study. However, this study has several limitations that should be considered when reviewing the results. First, the use of administrative data limits our ability to deduce causation or account for some other confounders which may affect the observed association, such as race, education, literacy, family history, the physical environment and type of cancer and treatments. Second, we focused on people with active cancers and excluded people in remission. This could have led to an underestimation of the prevalence of cancer. Third, long-term care homes

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experienced a different trajectory of COVID-19 exposure and outcomes and were therefore excluded from the study. The impact of COVID-19 outcomes on immigrants living in LTC homes remains unexplored. Fourth, there may be some misclassification of immigration status owing to the nature of the data. As the IRCC database started on Jan 1, 1985, immigrants who landed in Ontario prior to this date will not be categorized as immigrants. Individuals who landed in Canada via another province and subsequently moved to Ontario would be misclassified. However, these misclassifications would pull the effect towards null. Fifth, the study did not include community health centres (CHCs) in the analysis. It is important to note that CHCs see a disproportionate number of newcomers and refugees within the primary care models. However, the proportion of Ontarians seen in CHCs is quite small. Sixth the generalizability of this research remains limited as this study explores the Ontario population specifically and other geographies may not have the same distribution by immigrant status. Seventh, changes made to Ontario's COVID-19 testing criteria throughout the pandemic may have affected access to COVID-19 screening among our study cohort and led to an undercount of the true number of confirmed cases. Eighth, we used the Ontario Marginalization Index to assign individuals to a summary level of neighbourhood marginalization, that although validated, may not reflect individual-level marginalization. This also holds true for our use of income neighbourhood as a proxy for individual income. Finally, our study did not assess the stage of cancer or the type of cancer treatments which may have contributed to higher rates of COVID-19 hospitalization, ICU admission and mortality. This represents an important area for future study.

Conclusion

In this population-based study in Ontario, Canada, we found that immigrants and refugees living with active cancers were significantly more likely to be diagnosed with, hospitalized for, admitted to the ICU for, and die from, COVID-19 than their peers. This is particularly stark in a universal health care system. We also observed a clear income gradient across COVID-19 outcomes and saw a protective effect for being in a Family Health Team primary care model. System-level interventions that include culturally specific targeted interventions are needed to protect those at the intersection of clinical and social disadvantage during pandemic recovery and in future crises.

Declarations:

Ethics approval and consent to participate

ICES (formerly known as Institute for Clinical Evaluative Sciences) is a prescribed entity under section 45 of Ontario's Personal Health Information Protection Act. Section 45 authorizes ICES to collect personal health information, without consent, for the purpose of analysis or compiling statistical information with respect to the management of, evaluation or monitoring of, the allocation of resources to or planning for all or part of the health system. Projects conducted under section 45, by definition, do not require review by a Research Ethics Board. This project was conducted under section 45, and approved by ICES' Privacy and Legal Office. All methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication

Not Applicable

Availability of data and material

All data generated or analyzed during this study are included in this published article.

Competing interest

The authors declare that they have no competing interests.

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Authors' contributions

L.M. and A.K. extracted and analyzed the data based on specifications provided by M.V and A.L. M.V and A.L processed and analyzed the data and drafted the manuscript. L.M and M.V prepared the tables and figures, figures. The rest of co-authors J.W., C.D., J.R., M.N., W.T., A.J., G.D., K.F., and R.H, reviewed the article critically for intellectual content. All authors gave final approval of the version to be published and agreed to serve as guarantors of the work.

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