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Measuring the impact of the COVID-19 pandemic on organized cancer screening and diagnostic follow-up care in Ontario, Canada: A provincial, population-based study

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ABSTRACT

It is essential to quantify the impacts of the COVID-19 pandemic on cancer screening, including for vulnerable sub-populations, to inform the development of evidence-based, targeted pandemic recovery strategies. We undertook a population-based retrospective observational study in Ontario, Canada to assess the impact of the pandemic on organized cancer screening and diagnostic services, and assess whether patterns of cancer screening service use and diagnostic delay differ across population sub-groups during the pandemic. Provincial health databases were used to identify age-eligible individuals who participated in one or more of Ontario's breast, cervical, colorectal, and lung cancer screening programs from January 1, 2019–December 31, 2020. Ontario's screening programs delivered 951,000 (−41%) fewer screening tests in 2020 than in 2019 and volumes for most programs remained more than 20% below historical levels by the end of 2020. A smaller percentage of cervical screening participants were older (50–59 and 60–69 years) during the pandemic when compared with 2019. Individuals in the oldest age groups and in lower-income neighborhoods were significantly more likely to experience diagnostic delay following an abnormal breast, cervical, or colorectal cancer screening test during the pandemic, and individuals with a high probability of living on a First Nation reserve were significantly more likely to experience diagnostic delay following an abnormal fecal test. Ongoing monitoring and management of backlogs must continue. Further evaluation is required to identify populations for whom access to cancer screening and diagnostic care has been disproportionately impacted and quantify impacts of these service disruptions on cancer incidence, stage, and mortality. This information is critical to pandemic recovery efforts that are aimed at achieving equitable and timely access to cancer screening-related care.

Abbreviations: CCC, ColonCancerCheck; CI, Confidence interval; COVID-19, Coronavirus disease 2019; FIT, Fecal immunochemical test; gFOBT, Guaiac fecal occult blood test; ICMS, Integrated Client Management System; LDCT, Low-dose computed tomography; Lung-RADS®, Lung CT Screening Reporting & Data System; MRI, Magnetic resonance imaging; OBSP, Ontario Breast Screening Program; OCSP, Ontario Cervical Screening Program; OR, Odds ratio; OHIP, Ontario Health Insurance Plan; OLSP, Ontario Lung Screening Program; RPDB, Registered Persons Database.

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1. Introduction

Cancer screening is a critical cancer prevention and control strategy. The Canadian province of Ontario has four organized cancer screening programs: the Ontario Breast Screening Program (OBSP), the Ontario Cervical Screening Program (OCSP), ColonCancerCheck (CCC), and the Ontario Lung Screening Program (OLSP). Their goal is to reduce morbidity and mortality from breast, cervical, colorectal, and lung cancer.

On March 11, 2020, the World Health Organization declared a global pandemic of coronavirus disease 2019 (COVID-19) (World Health Organization, 2020). To mitigate transmission of COVID-19 and preserve health system capacity, in mid-March the Ontario government directed scheduled surgery to be ramped down and non-essential clinical activity to be ceased (Ontario Ministry of Health, 2020). Consequently, Ontario Health, the agency that oversees the delivery of healthcare across the province, recommended that cancer screening be paused, and suspended the mailing of fecal immunochemical test (FIT) kits and letters to invite, recall, and remind eligible screening participants. To manage constraints on health system capacity, pandemic guidance was developed for prioritizing cancer screening services according to cancer risk and prioritizing diagnostic services according to risk of morbidity and mortality (Ontario Health (Cancer Care Ontario), 2020a; Ontario Health (Cancer Care Ontario), 2020b; Ontario Health (Cancer Care Ontario), 2020c; Ontario Health (Cancer Care Ontario), 2020d; Ontario Health (Cancer Care Ontario), 2020e; Ontario Health (Cancer Care Ontario), 2020f; Ontario Health (Cancer Care Ontario), 2020g). Following a decrease in COVID-19 transmission, cancer screening was permitted to resume gradually at the end of May 2020.

The population benefits of cancer screening programs are dependent upon high coverage of the eligible population, as well as complete, timely, and accurate diagnostic follow-up. Disruption to screening and diagnostic services caused by the pandemic will likely reduce the expected benefits. Disparities in cancer screening and diagnostic follow-up care existed prior to the pandemic, according to factors such as immigrant status, income, and rurality (Vahabi et al., 2015; Honein-Abou-Haidar et al., 2013; Lofters et al., 2019a; Lofters et al., 2018; Lofters et al., 2007; Lofters et al., 2019b; Canadian Partnership Against Cancer, 2014a). Research has also demonstrated cancer disparities for Indigenous populations in Ontario compared with other Ontarians (Sheppard et al., 2010; Sheppard et al., 2020; Jull et al., 2019; Chan et al., 2019; Tungasuvvingat Inuit and Cancer Care Ontario, 2017; Métis Nation of Ontario and Cancer Care Ontario, 2015; Chiefs of Ontario, Cancer Care Ontario and Institute for Clinical Evaluative Sciences, 2017; Withrow et al., 2014). Without First Nations, Inuit and Métis identifiers in the provincial administrative health databases, however, little is known about how most aspects of the cancer system are performing for Indigenous peoples.

These same populations that experience disparities in screening (i.e., immigrants, racialized communities, low-income individuals, Indigenous peoples) have been disproportionately impacted by the pandemic due to their increased risk for contracting COVID-19 and/or experiencing severe health or economic consequences (Guttmann et al., 2020; United Nations, 2020). The disproportionate impact of COVID-19 may itself impact access to screening for marginalized communities. It is essential to quantify the impacts of the pandemic on the cancer screening pathway, and to determine whether existing disparities have widened. This evidence will inform the need for targeted pandemic recovery strategies. Thus, the objectives of this retrospective observational study in Ontario were to: (i) assess the impact of the pandemic on organized cancer screening and diagnostic services; and (ii) assess whether patterns of cancer screening test use and diagnostic delay differ across population sub-groups during the pandemic.

2. Methods

2.1. Study population

Health services are delivered to Ontario's population of 14.7 million through a publicly funded single-payer healthcare system. All age-eligible individuals who participated in one or more of Ontario's organized cancer screening programs from January 1, 2019–December 31, 2020 were included. The OBSP began in 1990 and screens average risk individuals aged 50–74 years with biennial mammography, and individuals aged 50–74 years with certain breast cancer risk factors with annual mammography (Chiarelli et al., 2020a). More than 90% of screening mammograms are performed within the OBSP, but some are performed opportunistically at facilities outside of the program. The OBSP is working to transition all facilities into the program to extend the benefits of organized screening to more screen-eligible Ontarians. The OBSP launched the first organized high risk breast screening program in Canada in 2011 and screens high risk individuals aged 30–69 years with annual mammography and magnetic resonance imaging (MRI) (Chiarelli et al., 2020b). The OCSP began in 2000 and screens individuals aged 21–69 years with a cervix with cervical cytology every three years (Cancer Care Ontario, 2021a). CCC began in 2008 and screens average risk individuals aged 50–74 years with biennial FIT (a self-administered test that can be completed at home) and individuals with a first-degree family history of colorectal cancer with colonoscopy (Cancer Care Ontario, 2021b). Prior to June 2019, CCC screened average risk individuals with the guaiac fecal occult blood test (gFOBT). Individuals with a first-degree family history are recommended to begin screening at age 50 or 10 years prior to their relative's diagnosis, at an interval of 5 years if their relative was diagnosed before age 60 or 10 years if their relative was diagnosed at age 60 or older. Ontario launched the Lung Cancer Screening Pilot for People at High Risk in 2017 and screens individuals aged 55 years and older at high risk for lung cancer at six hospitals across Ontario with low-dose computed tomography (LDCT) (Darling et al., 2020). Eligibility is determined using a modified version of the lung cancer risk prediction model developed by Tammemägi et al. (PLCOm2012noRace) (Tammemägi et al., 2013). People with a $\geq$ 2% risk of developing lung cancer over the next six years are eligible (Tammemägi et al., 2021). The pilot transitioned to the OLSP on April 1, 2021, becoming Canada's first organized lung screening program.

Ontario Health (Cancer Care Ontario) is designated a "prescribed entity" for the purposes of section 45(1) of the Personal Health Information Protection Act of 2004. As a prescribed entity, Ontario Health (Cancer Care Ontario) is authorized to collect personal health information from health information custodians without the consent of the patient, and to use such personal health information for the purpose of analysis or compiling statistical information with respect to the management, evaluation or monitoring of the allocation of resources to or planning for all or part of the health system, including the delivery of services. Because this study is in compliance with privacy regulations, ethics review was not required.

2.2. Measures and data sources

Information on cancer screening and diagnostic assessment was extracted from provincial health databases. For breast screening, data on mammogram and MRI visits, abnormal screening results and date of diagnosis were obtained from the OBSP's Integrated Client Management System (ICMS). Diagnostic delay was defined as the date of diagnosis (with or without tissue biopsy) occurring >7 weeks following an abnormal average risk screening mammogram or high risk screening episode (mammogram and MRI within 30 days), aligning with the average risk national target of ≥90% of cases within 7 weeks if tissue biopsy is performed (Canadian Partnership Against Cancer, 2017a).

For the OCSP, cervical cytology data were obtained from Cytobase, a database which includes cervical cytology test results analyzed in most

community-based laboratories in Ontario and accounts for approximately 90% of cervical cytology tests completed in the province (Inscyte Corporation, 2020). Following a high-grade cytology result, participants are recommended to receive colposcopy (Cancer Care Ontario, 2021a). The Ontario Health Insurance Plan (OHIP) Claims History Database, which contains billing information for healthcare services delivered by Ontario physicians, was used to identify colposcopy visits. The provincial recommendation for time to colposcopy is within 6 weeks of the referral date for people with high-grade abnormal results including atypical squamous cells cannot exclude high-grade squamous intraepithelial lesion or atypical glandular cells (Murphy et al., 2015). As data on the date of referral to colposcopy are not centrally available in Ontario, delay to colposcopy was defined as colposcopy occurring >10 weeks following a high-grade cytology result, based on the mean wait time from abnormal fecal test to colonoscopy referral in Ontario.

For colorectal screening, fecal test data were obtained from Ontario Health's Laboratory Reporting Tool and FIT Data Submission Portal. Colonoscopy visit data were obtained from the OHIP Claims History Database and Ontario Health's Gastrointestinal Endoscopy Data Submission Portal. Individuals with abnormal fecal test results are recommended to receive follow-up with colonoscopy and the current national target is ≥90% within two months of the abnormal fecal test result (Paterson et al., 2006; Canadian Partnership Against Cancer, 2017b). Thus, delay to colonoscopy was defined as the colonoscopy occurring >8 weeks following an abnormal fecal test.

Data on LDCT scans and OLSP participant characteristics were obtained from data files submitted to Ontario Health by lung cancer screening sites. Data on participant age were obtained from the ICMS for the OBSP, and by linkage to the Registered Persons Database (RPDB) for the OCSP and CCC. Participant sex was obtained from the RPDB for CCC. Before-tax neighborhood income and rurality were obtained by linking screening participants' postal code of residence (obtained from the ICMS or RPDB) to Statistics Canada's Postal Code Conversion File Plus, which links Canadian postal codes with standard 2016 census geographic areas and data. Neighborhood income was categorized into five quintiles (Q1 [lowest]–Q5 [highest]) defined by Statistics Canada. Rurality was categorized as follows: urban (population ≥ 10,000 and ≥ 50% of the population commute to a census metropolitan area or census agglomeration), rural (<10,000 and 30–49% of the population commute to an urban area), rural-remote (<10,000 and 5–29% of the population commute to an urban area), or rural-very remote (<10,000 and 0–4% of the population commute an urban area). Where participants were screened more than once with the same screening test during the analytic period, characteristics of the participant at their first screen were reported.

The largest population of Indigenous people in Canada live in Ontario, including an estimated 236,680 First Nations, 120,585 Métis and 3360 Inuit in 2016 (Statistics Canada, 2016). For the OLSP, Indigenous status (First Nations, Inuit, Métis, other) was self-reported by screening participants. For other programs, residential postal codes were used to identify a sub-set of participants residing in areas with high proportion of Indigenous people (≥0.90%) which are reflective of First Nations residing on a reserve. Acknowledging this study is provincial in scope, further work is needed to explore Indigenous-specific findings that could be generated from this study to inform mutual commitments to work with and for Indigenous partners to improve cancer care and outcomes.

2.3. Statistical analysis

A descriptive analysis was performed to quantify the impact of the pandemic on cancer screening volumes. Differences between monthly volumes performed in 2020 and corresponding 2019 periods were calculated, reporting changes in absolute volumes and percentages for programs combined, and percentage changes for each program. Proportions of screening test volumes by screen type or indication were examined from January 1–December 31, 2020. Distributions of participant characteristics were compared for March–December 2019 versus March–December 2020.

The numbers and rates of screening test abnormalities, diagnostic assessment completion status, and wait time were calculated by month from January 1–June 30, 2020 and compared with calendar year 2019. Associations between participant characteristics and diagnostic delay were modeled using unadjusted logistic regression to estimate odds ratios (OR) and corresponding 95% confidence intervals (CI). Statistical tests were two-sided and evaluated significance at a < 5% testing level. All analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC).

3. Results

3.1. Cancer screening test volumes and participant characteristics

Ontario's cancer screening programs delivered 1,352,858 screening tests in 2020 compared to 2,304,657 in 2019, representing a reduction of 41.3% (Table 1). There were 455,592 fewer (−72.9%) screens delivered from March–May 2020 relative to this period in 2019, after which volumes began to recover.

The increase observed in screening volumes for all programs in January–February 2020 was primarily driven by increases in the OBSP (likely due to the transition of additional sites into the program) and CCC (likely due to the transition from gFOBT to FIT), and in part due to increases within the three lower-volume high/increased risk programs (Fig. 1). For screening tests that require an in-person visit to a primary care provider or screening site (OBSP, High Risk OBSP, OCSP, Increased Risk CCC, OLSP), volumes declined by 16.4%–48.6% in March 2020 and from 85.8%– to 99.8% in April and May 2020. For the average risk CCC, volume declined by 4.4% in March 2020 (reflecting the return of FIT kits that were sent to participants prior to the pause in FIT kit mailing) and by 78.3% in April, while the largest reductions were observed in May (90.4%) and June (91.3%), after which the volume began to recover as the mailing of FIT kits gradually resumed. The High Risk OBSP and OLSP volumes exceeded 2019 volumes as of July and August 2020, respectively, while volumes for other programs were 20.2%–22.8% below 2019 levels as of December 2020. Prioritization of cancer screening and diagnostic services for higher risk groups was observed for all programs examined (Supplement Fig. 1–4).

Relative to 2019, a higher percentage of OCSP participants in the pandemic period were 21–29 years (19.9% vs. 17.3%) and 30–39 years (25.9% vs. 23.2%) and a lower percentage were 50–59 years (19.6% vs. 22.0%) and 60–69 years of age (13.9% vs. 15.8%) (Table 2). Conversely, during the pandemic, a lower percentage of OLSP participants were 55–59 years (15.0% vs. 19.2%) and a higher percentage were 70+ years of age (24.7% vs. 21.1%) compared to 2019 (Table 3). Characteristics of those screened for breast and colorectal cancer were similar in 2019 and 2020.

3.2. Abnormal results, diagnostic assessment and participant characteristics

The abnormal call rate for average risk screening mammography in 2019 was 8.8% (range = 8.2%–9.3%), with nearly all participants completing diagnostic assessment and 91.3% (range = 88.5%–92.4%) with a final diagnosis (with and without tissue biopsy) within 7 weeks (Table 4). Abnormal call rate increased above 10% from April–June 2020, consistent with the higher proportion of annual/one-year mammograms performed in this period (Supplement Fig. 1). The abnormal rate in the High Risk OBSP similarly increased in April–June 2020 (range = 21.1%–37.3%), consistent with the higher proportion of screening episodes in participants with genetic mutations or history of chest radiation (i.e., the highest risk groups) (Supplement Fig. 2). The percentage of participants screened in June 2020 who had not received a

Table 1
Cancer screening test volumes for the OBSP, High Risk OBSP, OCSP, CCC, Increased Risk CCC and OLSP, by time period,[^] January 1, 2019–December 31, 2020.

	January–February	March–May	June–December[b]	January–December[b]
2019	341,367	624,460	1,338,830	2,304,657
2020	385,700	168,973	798,185	1,352,858
Volume change	+44,333	−455,487	−540,645	951,799
Percentage change	+13.0%	−72.9%	−40.4%	−41.3%

[^] January–February 2020 (pre-pandemic), March–May (screening suspension), June–December (screening resumption).
[b] Volumes are underestimated by approximately 700 in 2020 as OLSP data were only available to November 30, 2020.

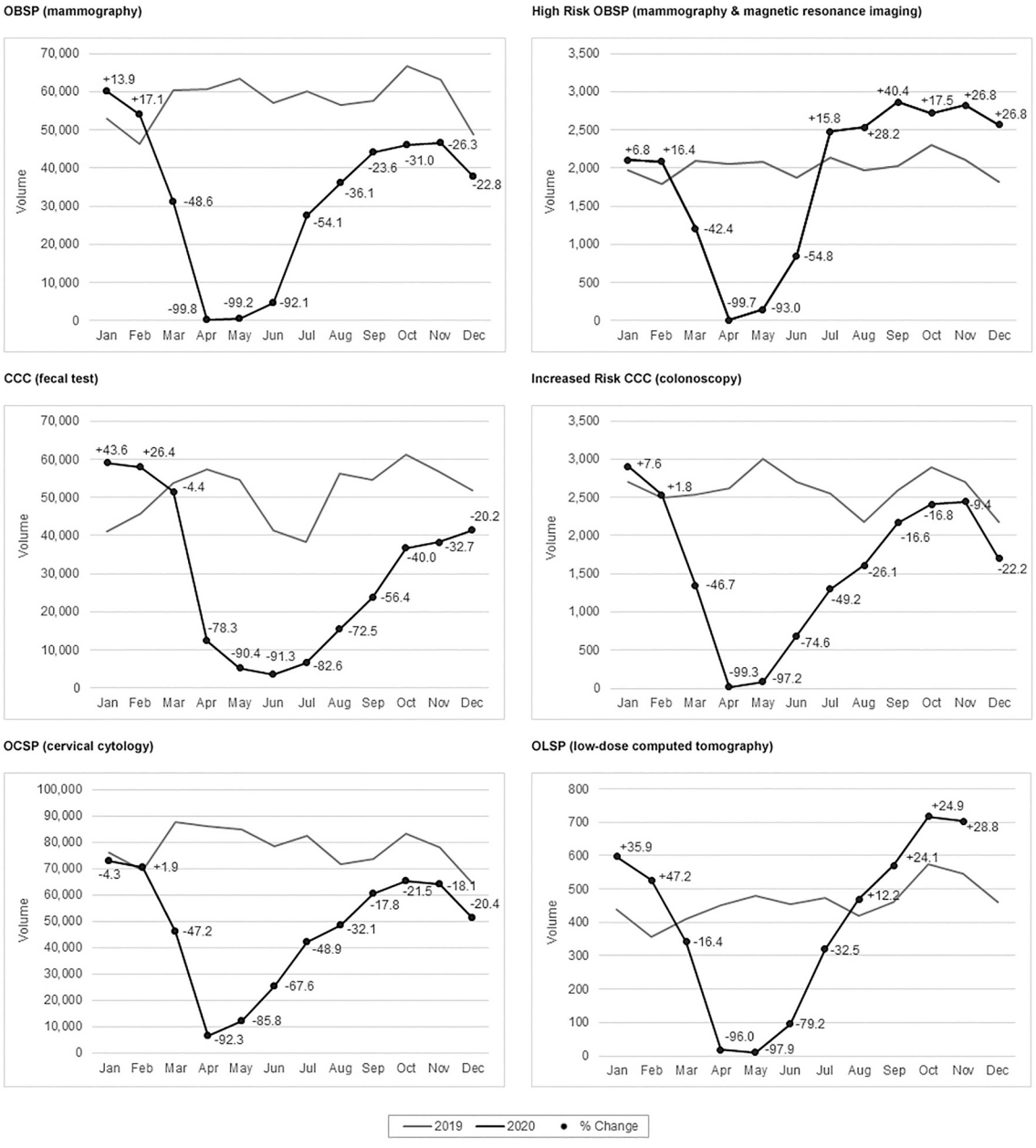

Fig. 1. Cancer screening test volumes, January 1, 2019–December 31, 2019 and January 1, 2020– December 31, 2020.

diagnosis was elevated above pre-pandemic levels for the average risk (1.8%) and High Risk OBSP (13.3%). The percentage of participants diagnosed within 7 weeks declined to approximately 80% in March and April 2020 for the average risk OBSP but returned to pre-pandemic levels by May 2020 (Table 4, Fig. 2). Conversely, the percentage of High Risk OBSP participants with a diagnosis within 7 weeks was higher in May (72.0%) 2020 relative to pre-pandemic levels (62.0%, range = 57.4%–65.7%); however, very few individuals underwent screening and received an abnormal result in this month.

For the OCSP in 2019, 55.8% (range = 51.2%–62.5%) of participants with a high-grade result underwent colposcopy within 10 weeks, and 9.0% (range = 6.3%–12.4%) did not receive colposcopy. The percentage of participants with a high-grade result that received colposcopy within 10 weeks was relatively stable through 2020, except for those screened

Table 2
Screening participant characteristics, March 1, 2019–December 31, 2019 and March 1, 2020–December 31, 2020.

Participant characteristic	OBSP & High Risk OBSP		OCSP		CCC & increased risk CCC	
	2019 N (%)	2020 N (%)	2019 N (%)	2020 N (%)	2019 N (%)	2020 N (%)
Participants, N	605,889	284,242	761,891	404,945	516,501	245,205
Sex						
Men	–	–	–	–	229,132 (44.4)	111,022 (45.3)
Women	–	–	–	–	287,354 (55.6)	134,176 (54.7)
Missing	–	–	–	–	15 (<0.1)	7 (<0.1)
Age[^]						
Band 1 (lowest)	2488 (0.4)	2022 (0.7)	131,878 (17.3)	80,748 (19.9)	897 (0.2)	538 (0.2)
Band 2	4265 (0.7)	3756 (1.3)	176,710 (23.2)	104,841 (25.9)	3345 (0.6)	1695 (0.7)
Band 3	268,114 (44.3)	125,028 (44.0)	165,245 (21.7)	83,950 (20.7)	221,067 (42.8)	104,816 (42.7)
Band 4	246,329 (40.7)	114,685 (40.3)	167,335 (22.0)	79,283 (19.6)	206,413 (40.0)	99,051 (40.4)
Band 5 (highest)	84,693 (14.0)	38,751 (13.6)	120,723 (15.8)	56,123 (13.9)	84,779 (16.4)	39,105 (15.9)
Neighborhood income quintile						
Q1 (lowest)	97,583 (16.1)	43,514 (15.3)	128,453 (16.9)	69,843 (17.2)	89,924 (17.4)	41,932 (17.1)
Q2	114,411 (18.9)	51,539 (18.1)	141,221 (18.5)	74,514 (18.4)	101,291 (19.6)	46,527 (19.0)
Q3	121,855 (20.1)	56,410 (19.8)	153,098 (20.1)	80,810 (20.0)	106,108 (20.5)	49,821 (20.3)
Q4	126,504 (20.9)	60,926 (21.4)	165,924 (21.8)	87,540 (21.6)	106,536 (20.6)	51,972 (21.2)
Q5 (highest)	141,196 (23.3)	69,740 (24.5)	170,294 (22.4)	90,593 (22.4)	109,192 (21.1)	54,197 (22.1)
Missing	4340 (0.7)	2113 (0.7)	2901 (0.4)	1645 (0.4)	3450 (0.7)	756 (0.3)
Rurality						
Urban	531,206 (87.7)	247,999 (87.2)	680,850 (89.4)	361,706 (89.3)	447,345 (86.6)	212,164 (86.5)
Rural	36,017 (5.9)	17,560 (6.2)	41,347 (5.4)	21,540 (5.3)	34,118 (6.6)	16,623 (6.8)
Rural-remote	23,925 (3.9)	11,631 (4.1)	24,517 (3.2)	12,899 (3.2)	22,659 (4.4)	11,123 (4.5)
Very remote	10,619 (1.8)	5045 (1.8)	12,551 (1.6)	7315 (1.8)	9133 (1.8)	4623 (1.9)
Missing	4122 (0.7)	2007 (0.7)	2626 (0.3)	1485 (0.4)	3246 (0.6)	672 (0.3)
Postal code overlap with First Nation reserve						
≥90% overlap	831 (0.1)	267 (0.1)	4716 (0.6)	2628 (0.6)	443 (0.1)	209 (0.1)
<90% overlap	604,901 (99.8)	283,874 (99.9)	757,175 (99.4)	402,317 (99.4)	514,652 (99.6)	244,967 (99.9)
Missing	157 (<0.1)	101 (<0.1)	0 (0.0)	0 (0.0)	1406 (0.3)	29 (<0.1)

[^] OBSP: 30–39, 40–49, 50–59, 60–69, 70–74 years. OCSP: 21–29, 30–39, 40–49, 50–59, 60–69 years. CCC: <40, 40–49, 50–59, 60–69, 70+ years.

in February when a lower percentage (49.5%) completed follow-up within 10 weeks (coinciding with the provincial suspension of non-emergent health services) (Table 2, Fig. 2). The percentage of participants for whom colposcopy was not performed was increased for participants with high-grade cervical cytology tests in April–June 2020 (range = 12.8%–21.1%.

Of CCC participants with a fecal test-positive result in 2019, 57.9% (range = 47.9%–67.5) had a colonoscopy within 8 weeks and 12.0% did not undergo colonoscopy. The percentage of participants with FIT-positive results who underwent colonoscopy within 8 weeks was lower from February–April 2020 (range = 33.2%–52.8%) (Fig. 2), after which it increased above 2019 levels in May (70.8%) and June (75.0%) however there were few individuals with FIT-positive results during these months. The percentage of participants who did not undergo follow-up colonoscopy remained relatively stable from January–June 2020 with the exception of those with an abnormal fecal test result in March (range excluding March = 9.2%–12.8%; March 2020 = 15.6%), which coincided with the reduction in colonoscopy volumes under the order to suspend non-emergent health services. In accordance with prioritization guidance, the percentage of FIT-positive colonoscopies increased and the percentage of screening colonoscopies decreased during the service suspension (Supplement Fig. 3).

For the OLSP, 9.3% (range = 6.2%–14.1%) of LDCT scans in 2019 had Lung-RADS® scores of 3/4A, and 2.9% (range = 2.1%–3.7%) had scores of scores of 4B/4X. The abnormal rate for both Lung-RADS® categories was stable in January–March 2020 but was elevated in April 2020 (16.7%). This rise in positivity corresponds to the fact that all scans completed in April 2020 were 3- or 6-month follow-up scans of previous Lung-RADS® 3/4A results (Supplement Fig. 4).

During the pandemic, individuals in the oldest age band for each cancer screening program were significantly more likely to experience diagnostic delay than those in the youngest band, including those 70–74 years who had an abnormal average risk OBSP screening mammogram (OR = 1.30, 95% CI: 1.09–1.54), those 60–69 years who had a high-grade cytology test result (OR = 1.78, 95% CI: 1.28–2.48) and those 70–74 years who had an abnormal FIT result (OR = 1.06, 95% CI: 1.00–1.12) (Table 5). The absolute difference between the youngest and oldest age bands was only 2.6% for the OBSP, while they were 5.6% and 14.3% for the CCC and OCSP, respectively. Individuals who lived in neighborhoods in the lowest income quintile were also significantly more likely to have had diagnostic delay following an abnormal mammogram than those in the highest quintile (OR = 1.28, 95% CI: 1.07–1.52). The likelihood of diagnostic delay following a positive FIT result increased with decreasing neighborhood income level (Q4 OR = 1.07, 95% CI: 1.01–1.14; Q3 OR = 1.13, 95% CI: 1.06–1.20; Q2 OR = 1.14, 95% CI: 1.07–1.21; Q1 OR = 1.28, 95% CI: 1.20–1.36 vs. Q5). Individuals residing in areas with ≥90% overlap with a First Nation reserve were 1.4–3.6 times more likely to experience diagnostic delay for any screening test; however, the numbers of individuals were very small and differences were only statistically significant for those with a positive FIT test (OR = 1.77, 95% CI: 1.05–3.00).

4. Discussion

The COVID-19 pandemic has profoundly impacted Ontario's cancer screening programs. In 2020, cancer screening test volumes were reduced by over 40% overall. Similar reductions have been reported by other jurisdictions (London et al., 2020; Epic Health Research Network, 2020; Peng et al., 2020; Lang et al., 2020; Song et al., 2020). As a result, backlogs have accumulated that may take several years to recover in the absence of capacity increases or other management strategies. One such management strategy is the redirection of low-yield colonoscopies (e.g., for average risk screening) to FIT, which is estimated to reduce Ontario's colonoscopy backlog recovery time by more than one year if redirection rates of 25% or greater are achieved (Tinmouth et al., 2020). Adherence to OBSP prioritization guidance is also expected to shorten

Table 3
OLSP participant characteristics, March 1, 2019–November 30, 2019 and March 1, 2020–November 30, 2020.

Participant characteristic	2019 N (%)	2020 N (%)
Participants, N	4095	3178
Sex		
Men	2211 (54.0)	1730 (54.4)
Women	1884 (46.0)	1448 (45.6)
Age, years		
55–59	786 (19.2)	477 (15.0)
60–69	2446 (59.7)	1917 (60.3)
70+	863 (21.1)	784 (24.7)
Neighborhood income quintile		
Q1 (lowest)	994 (24.3)	752 (23.7)
Q2	903 (22.1)	702 (22.1)
Q3	788 (19.2)	636 (20.0)
Q4	735 (18.0)	567 (17.8)
Q5 (highest)	645 (15.8)	487 (15.3)
Missing	30 (0.7)	34 (1.1)
Rurality		
Urban	3311 (80.9)	2550 (80.2)
Rural	415 (10.1)	303 (9.5)
Rural-remote	298 (7.3)	257 (8.1)
Very remote	41 (1.0)	34 (1.1)
Missing	30 (0.7)	34 (1.1)
Postal code overlap with First Nation reserve		
≥90% overlap	15 (0.4)	13 (0.4)
<90% overlap	4077 (99.6)	3157 (99.3)
Missing	3 (0.1)	8 (0.3)
Self-identified Indigenous status		
First Nations	110 (2.7)	90 (2.8)
Inuit	^	^
Métis	116 (2.8)	84 (2.6)
Other	^	^
Non-Indigenous	3535 (86.3)	2719 (85.6)
Missing	309 (7.6)	257 (8.1)

^ Data suppressed due to small cells.

mammography backlog recovery time for those at higher risk for breast cancer. The identification and use of such strategies will be of ongoing importance as COVID-19 infections continue to surge in 2021, and backlogs continue to accumulate within most programs. These backlogs may lead to further diagnostic delays, as well as a likely increase in cancer diagnoses when screening utilization fully resumes, which will in turn impact downstream cancer services.

The recoveries of screening programs are impacted by numerous factors, such as the mode of delivery (i.e., mailed FIT kits for self-completion vs. in-person visit to a health care provider for other programs), capacity at screening sites and primary care practices (including availability of personal protective equipment, health human resources, and physical space) and ongoing community transmission of COVID-19. Individual decision-making regarding use of in-person healthcare during an ongoing pandemic is complex; knowledge, beliefs, fears, lifestyle, experience and external cues (e.g., media, healthcare providers, social networks) play a role in making a decision about health. Many individuals have experienced changes in their personal conditions (e.g.,

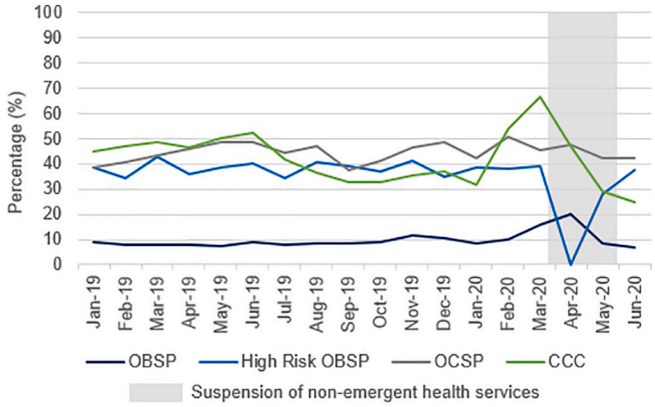

Fig. 2. Percentage of screening participants with an abnormal screening result who experienced diagnostic delay, according to the month of the abnormal screening test, January 1, 2019–June 30, 2020.

Table 4
Diagnostic assessment status[1] according to month of the abnormal screening test, 2019 and January 1–June 30, 2020.

	2019		2020					
	N	% (Range)	January N (%)	February N (%)	March N (%)	April N (%)	May N (%)	June N (%)
Abnormal OBSP screening mammograms	60,796	8.8 (8.2–9.3)	5381 (8.9)	5073 (9.4)	2645 (8.5)	15 (10.1)	59 (11.0)	512 (11.3)
Diagnosis ≤7 weeks[2]	55,477	91.3 (88.5–92.4)	4925 (91.5)	4573 (90.1)	2221 (84.0)	12 (80.0)	54 (91.5)	478 (93.4)
Awaiting diagnosis[3]	47	0.1 (0.0–0.2)	5 (0.1)	13 (0.3)	10 (0.4)	0 (0.0)	0 (0.0)	9 (1.8)
Abnormal High Risk OBSP screening episodes[4]	2024	18.6 (15.8–21.0)	181 (19.4)	175 (18.4)	105 (19.2)	^	25 (37.3)	76 (21.1)
Diagnosis ≤7 weeks[2]	1269	62.0 (57.4–65.7)	112 (61.5)	109 (61.9)	64 (61.0)	^ (100.0)	18 (72.0)	54 (71.7)
Awaiting diagnosis[3]	27	1.9 (0.0–4.4)	^	^	0 (0.0)	0 (0.0)	0 (0.0)	10 (13.3)
High-grade OCSP cervical cytology test results[5]	6896	0.7 (0.7–0.8)	598 (0.8)	539 (0.8)	352 (0.8)	128 (1.9)	203 (1.7)	331 (1.3)
Colposcopy ≤10 weeks	3839	55.8 (51.2–62.5)	345 (57.7)	267 (49.5)	192 (54.5)	67 (52.3)	117 (57.6)	192 (58.0)
Awaiting colposcopy[3]	618	9.0 (6.3–12.4)	60 (10.0)	58 (10.8)	39 (11.1)	27 (21.1)	26 (12.8)	49 (14.8)
Positive CCC fecal test results	24,865	*	2828 (*)	2665 (*)	2330 (*)	593 (*)	233 (*)	120 (*)
Colonoscopy ≤8 weeks	14,676	57.9 (47.9–67.5)	1932 (68.3)	1231 (46.2)	774 (33.2)	313 (52.8)	165 (70.8)	90 (75.0)
Awaiting colonoscopy[3]	2888	12.0 (8.6–16.0)	319 (11.3)	340 (12.8)	363 (15.6)	71 (12.0)	24 (10.3)	11 (9.2)
Lung-RADS® 3 & 4A OLSP LDCT scan results	506	9.3 (6.2–14.1)	39 (6.5)	30 (5.7)	28 (8.2)	^ (16.7)	^ (10.0)	7 (7.4)
Lung-RADS® 4B & 4X OLSP LDCT scan results	159	2.9 (2.1–3.7)	18 (3.0)	19 (3.6)	9 (2.6)	^ (16.7)	0 (0.0)	6 (6.3)

^ Data suppressed due to small cells.
* Data unavailable.
1: Participants undescribed include those who received a diagnosis >7 weeks following abnormal mammogram, those who underwent colposcopy >10 weeks following a high-grade cytology test and those who underwent colonoscopy >8 weeks following a positive fecal test. Diagnostic assessment data are not reported for the OLSP due to a data reporting lag.
2: With or without tissue biopsy.
3: No diagnosis (OBSP, High Risk OBSP), colposcopy (OCSP) or colonoscopy (CCC) as of March 2021.
4: High Risk OBSP screening episodes where the mammogram and MRI occurred within 30 days.
5: Atypical squamous cells, cannot exclude high-grade squamous intraepithelial lesion, high-grade squamous intraepithelial lesion, atypical glandular cells, adenocarcinoma in situ.

Table 5
Odds ratios and 95% confidence intervals for associations between participant characteristics and diagnostic delay during the COVID-19 pandemic, January 1–June 30, 2020.

Participant characteristic	Abnormal OBSP mammograms[1] $N = 13,685$		High-grade OCSP cytology tests $N = 2151$		Positive CCC fecal tests $N = 8769$	
	Diagnosis > 7 weeks[2] N (%)	Odds ratio (95% CI)	Colposcopy > 10 weeks N (%)	Odds ratio (95% CI)	Colonoscopy > 8 weeks N (%)	Odds ratio (95% CI)
Participants	1422 (10.4)	–	971 (45.1)	–	4264 (48.6)	–
Sex						
Men	–	–	–	–	2508 (48.2)	1.00
Women	–	–	–	–	1756 (49.2)	1.01 (0.97–1.05)
Age[3]						
Band 1 (lowest)	726 (9.8)	1.00	231 (44.0)	1.00	1443 (46.6)	1.00
Band 2	516 (10.7)	1.10 (0.98–1.24)	290 (39.9)	0.84 (0.67–1.06)	1870 (48.6)	1.02 (0.98–1.06)
Band 3	180 (12.4)	1.30 (1.09–1.54)	174 (45.1)	1.05 (0.80–1.36)	951 (52.2)	1.06 (1.00–1.12)
Band 4	–	–	160 (51.0)	1.32 (1.00–1.75)	–	–
Band 5 (highest)	–	–	116 (58.3)	1.78 (1.28–2.48)	–	–
Neighborhood income quintile						
Q1 (lowest)	272 (11.8)	1.28 (1.07–1.52)	207 (47.8)	1.03 (0.79–1.35)	922 (52.2)	1.28 (1.20–1.36)
Q2	264 (10.5)	1.11 (0.93–1.33)	180 (42.0)	0.81 (0.62–1.07)	923 (49.1)	1.14 (1.07–1.21)
Q3	268 (9.8)	1.04 (0.87–1.23)	202 (44.6)	0.90 (0.69–1.18)	857 (48.5)	1.13 (1.06–1.20)
Q4	308 (10.8)	1.15 (0.98–1.36)	185 (44.7)	0.91 (0.69–1.19)	826 (47.3)	1.07 (1.01–1.14)
Q5 (highest)	298 (9.5)	1.00	195 (47.1)	1.00	721 (45.6)	1.00
Rurality						
Urban	1269 (10.5)	1.00	860 (45.6)	1.00	3631 (49.1)	1.00
Rural	70 (9.4)	0.88 (0.68–1.14)	53 (41.7)	0.86 (0.60–1.23)	290 (43.6)	0.85 (0.79–0.92)
Rural-remote	53 (10.3)	0.98 (0.73–1.31)	36 (41.4)	0.84 (0.55–1.31)	221 (46.7)	0.96 (0.88–1.06)
Very remote	19 (10.0)	0.95 (0.59–1.53)	20 (48.8)	1.14 (0.61–2.11)	109 (52.4)	1.12 (0.98–1.28)
Postal code overlap with First Nation reserve						
≥90% overlap	^	1.44 (0.42–4.90)	^	3.65 (0.38–35.08)	7 (63.3)	1.77 (1.05–3.00)
<90% overlap	^	1.00	^	1.00	4257 (48.6)	1.00

^ Data suppressed due to small cells.
1: Average risk OBSP.
2: With or without tissue biopsy.
3: OBSP (average risk): 50–59, 60–69, 70–74 years. OCSP: 21–29, 30–39, 40–49, 50–59, 60–69 years. CCC (average risk): 50–59, 60–69, 70–74 years.

lack of childcare) that have led to new competing priorities. Prospect Theory (Kahneman and Tversky, 1979) suggests that individuals are likely to weigh the risk of COVID-19 transmission more heavily than the potential gains of cancer prevention, and choose to postpone cancer screening until the risk of cancer outweighs the risk of COVID-19 infection.

The pandemic has also worsened the impacts of the social determinants of health for those who have experienced loss of income, housing, or both. Mailed correspondence is a main recruitment mechanism for Ontario's cancer screening programs. A recent Ontario study found that more than 20% of women eligible for cervical screening correspondence were not reachable due to address quality issues in the databases (Clark et al., 2019). As many individuals have relocated during the pandemic, the reach of mailed correspondence programs may be further challenged. Strategies such as e-correspondence or social media campaigns may have the potential to improve reach to screen-eligible populations.

A previous evaluation of Ontario's screening programs found that the youngest and oldest age-eligible groups and lowest income neighborhoods had higher proportions of individuals overdue for screening (Cancer Care Ontario, 2016). Other Ontario studies have demonstrated lower rates of screening among recent immigrants and those living in lower-income neighborhoods (Vahabi et al., 2015; Honein-AbouHaidar et al., 2013; Lofters et al., 2019a; Lofters et al., 2018; Lofters et al., 2007; Lofters et al., 2019b). Similar findings have been noted across Canada (Buchman et al., 2016; Simkin et al., 2019), and other jurisdictions (Klabunde et al., 2011; Pornet et al., 2014; von Wagner et al., 2011). In our study, a smaller proportion of OCSP participants during the pandemic were from older age groups, and older individuals were also less likely to receive timely diagnostic assessment in any program. This suggests that the existing disparity for older individuals – women in particular – may have widened as a result of the pandemic. While in certain cases it may be appropriate to delay cancer screening for a number of months during the pandemic (e.g., for those at average risk for cancer that have risk factors for experiencing poor health outcomes from COVID-19), extensive delays in screening may not be appropriate for those at high risk for developing cancer, and abnormal screening results continue to require prompt diagnostic follow-up. The spike in incomplete diagnostic assessment observed in March and April is concerning; the abrupt shut-down of health services and messaging instructing people to stay home may have increased the likelihood of individuals not undergoing follow-up. Optimistically, we observed only short-term overall increases in diagnostic delay at the outset of the suspension of non-emergent health services. However, rates of timely assessment for abnormal breast or colorectal cancer screens were lower for those in lower-income neighborhoods, which may contribute to poorer cancer survival observed in lower-income groups (Mackillop et al., 1997; Canadian Partnership Against Cancer, 2014b).

It has been demonstrated that similar proportions of First Nations, Inuit, Métis and non-Indigenous women undergo timely cervical cancer screening (Tungasuvvingat Inuit and Cancer Care Ontario, 2017; Métis Nation of Ontario and Cancer Care Ontario, 2015; Chiefs of Ontario, Cancer Care Ontario and Institute for Clinical Evaluative Sciences, 2017; Withrow et al., 2014) but significantly lower rates of screening mammography have been observed in First Nations women living on-reserve and Métis women compared with non-Indigenous women (Chiefs of Ontario, Cancer Care Ontario and Institute for Clinical Evaluative Sciences, 2017; Withrow et al., 2014). Under-screening for colorectal cancer is also higher in First Nations men living off-reserve and Métis men compared with non-Indigenous men (Withrow et al., 2014). Our analysis suggested that similar proportions of individuals residing in areas that overlap with First Nation reserves were screened in 2019 and 2020, but these individuals were more likely to experience diagnostic delay following an abnormal screening test. The number of

individuals in the subset of Indigenous populations in Ontario included in our study who underwent cancer screening, however, was very small. It is critical to partner with Indigenous communities and organizations to improve the identification of First Nations, Inuit and Métis peoples within the databases. As the disparities for older individuals, lower-income individuals, and Indigenous peoples demonstrated by our analysis are not new, it is essential that pandemic recovery efforts aim not to merely restore services to a pre-pandemic state but focus on achieving equitable access to cancer screening and diagnostic care for all Ontarians.

Disruption to cancer screening services will result in fewer screen-detected pre-cancers and cancers. Based on the screening volume reductions we observed and assuming similar detection rates as previously reported for our programs (Ontario Health (Cancer Care Ontario), 2021), there may have been 1412–1507 fewer invasive breast cancers, 1148–1222 fewer invasive cervical cancers and cervical pre-cancers, and 393–462 fewer invasive colorectal cancers detected in 2020. Several years of follow-up will be required to determine whether this will translate to clinically meaningful changes in cancer incidence and stage at diagnosis, and poorer cancer outcomes (e.g., mortality, survival, quality of life). While we cannot yet quantify these downstream impacts, a recent modeling study estimated that for a three-month interruption to screening in Canada, an additional 310 persons with advanced-stage breast cancers, 110 breast cancer deaths, 1100 persons with colorectal cancers, and 480 colorectal cancer deaths would result, with further excess death if volumes were constrained following screening resumption (Yong et al., 2020). Another study estimated 630 excess cervical cancers following a six-month cervical screening disruption in England (Castanon et al., 2020). Others have projected increases in avoidable death from pandemic-related diagnostic delays in the UK from breast cancer (7.9–9.6%), colorectal cancer (15.3–16.6%), and lung cancer (5.8–6.0%) (Maringe et al., 2020), and that diagnostic delays of even three months following an abnormal screen will result in fewer cervical and colorectal cancers prevented and a less favorable stage distribution for breast and colorectal cancer (Rutter et al., 2018).

This study has several strengths including the use of high-quality, population-level, timely databases. Coverage of virtually all individuals who participated in Ontario's four organized cancer screening programs and inclusion of both the screening and diagnostic phases of the screening pathway are also novel features of our study. Generalizability is likely extended to the broader population of Ontarians who participate in cancer screening who were not covered by our databases. However, the pre−/post-analysis could not account for non-pandemic related events that occurred during the same period as the pandemic. For example, it is not possible to determine whether the difference in OLSP participant age is related to the pandemic (e.g., the prioritization of abnormal screen recalls), the ongoing recruitment of participants to the new program, or aging of current participants. Due to an OHIP data lag, the percentage of individuals awaiting colposcopy or colonoscopy may be slightly overestimated (<10%) for May and June 2020. In the absence of individual-level information on income, we used neighborhood income which leaves our findings open to ecological fallacy. While agreement between individual- and area-level income is low, area-level income is an independent predictor of health outcomes (Buajitti et al., 2020). While the methodology we employed is highly accurate for identifying those with a high probability of living on a First Nation reserve in Northern areas of the province, these postal codes cover only an estimated 40% of Indigenous populations in Ontario. This method also aggregates Indigenous communities who are likely to have differing experiences with COVID-19 and the healthcare system. We also could not examine other sub-populations of interest, such as foreign-born and racialized populations due to a lack of birthplace and race-based data.

5. Conclusion

Findings of this province-wide study on the impact of the COVID-19 pandemic on cancer screening and diagnostic assessment in Ontario demonstrate unprecedented impacts that will have long-term effects. Our findings suggest the pre-existing cervical screening gap for older persons may be widened by the pandemic, and that older individuals, those living in lower-income neighborhoods, and those living in an area with a high concentration of First Nations people are less likely to receive timely diagnostic follow-up during the pandemic. Monitoring of screening-related service volumes and backlogs must continue. Further research and evaluation is also required to identify populations for whom cancer screening and diagnostic access has been disproportionately impacted by the pandemic and quantify the impacts of these service disruptions on morbidity, mortality, and quality of life. This information is critical to support targeted, evidence-based recovery efforts that are aimed at reducing screening gaps and achieving equitable and timely access to cancer screening-related care.

Conflict of interest declaration

The authors have no competing interests to declare.

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Author contributions

MW, JG, AC, and LR conceived the study. All authors contributed to the design of the study. JG, GE, NJ and MW analyzed the data. MW interpreted the data and prepared the initial draft. OM, JG, GE, NJ, CB, AS, UA, MR, AL, MT, JT, RK, AC and LR reviewed and critically revised the article. All authors reviewed and approved the final article for submission and publication.

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

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