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Consequences of delaying non-urgent surgeries during COVID-19: a population-based retrospective cohort study in Alberta, Canada

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ABSTRACT

Objectives To ensure sufficient resources to care for patients with COVID-19, healthcare systems delayed non-urgent surgeries to free capacity. This study explores the consequences of delaying non-urgent surgery on surgical care and healthcare resource use.

Design This is a population-based retrospective cohort study.

Setting This study took place in Alberta, Canada, from December 2018 to December 2021.

Participants Adult patients scheduled for surgery in Alberta during the study period were included.

Primary and secondary outcomes measures The proportion of surgeries completed and surgery wait time were the primary outcomes. The secondary outcomes were healthcare resource use (hospital length of stay, emergency room visits and physician visits). The association between the primary outcomes and patient and surgery-related variables was explored using regression.

Results There were 202 470 unique patients with 259 677 scheduled surgeries included. Fewer surgeries were completed throughout the pandemic compared with before; in the fourth wave, there was a decrease from 79% pre-COVID-19 to 67%. There was a decrease in wait time for those who had surgery completed during COVID-19 (from 105 to 69 days). Having surgery completed and the wait for surgery were associated with the geographical zone, COVID-19 wave, and the surgery type and priority. There was a decrease in all measures of healthcare resource use and an increase in hospital and all-cause mortality during COVID-19 compared with before COVID-19.

Conclusions The change in the proportion of scheduled surgeries completed and the wait time for completed surgery was modest and associated with COVID-19 wave and surgery-related variables, which was aligned with policies enacted during COVID-19 for surgery. The decrease in healthcare resource use suggests the effects of the COVID-19 pandemic may be delayed and may result in many patients presenting with advanced disease requiring surgical care.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This study was population based and included all patients booked for surgery in a large province.
⇒ This study compared the year before COVID-19 to the first four waves of COVID-19.
⇒ It is likely that this study underestimates the number of patients whose access to surgical care was compromised due to the COVID-19 pandemic because we were only able to include patients who had a surgery scheduled and did not capture patients who were not able to be booked for surgery.
⇒ The generalisability of these findings should consider the context of the setting, including the number of COVID-19 cases, hospitalisations (including intensive care unit) and deaths; and policies about providing surgical care during the pandemic.

INTRODUCTION

The novel SARS-CoV-2 virus (COVID-19) was declared a pandemic in March 2020 by the WHO.[1] The pandemic led to a large influx of patients with COVID-19 that required care in hospitals and intensive care units (ICUs). To accommodate this large number of patients with COVID-19, strategies were developed to create surge capacity within hospitals (ie, free up hospital and ICU beds and staff to care for COVID-19 patients), such as delaying or cancelling non-urgent surgeries (not immediately life-threatening).[2 3] Due to the pandemic's novel and rapidly evolving nature, these strategies were developed in the absence of high-quality evidence. Delaying non-urgent scheduled surgeries on the scale seen during COVID-19 is unprecedented; a modelling study estimates that globally there were over 28 million surgeries postponed during the peak of COVID-19 disruptions.[4] The consequences of these decisions on patients and the healthcare system are only beginning to become evident. Evidence has outlined psychosocial impacts on patients (increased distress),[5] and morbidity and mortality (patients waiting for surgery during

COVID-19 were more than three times more likely to die than patients before COVID-19),[6] and system-wide consequences of delayed surgery are emerging such as disruptions in cancer care (extended wait time for cancer surgery led to 843 years of life lost in one province and fewer detected cancers).[7 8] Still, many studies continue to be small, single-centre studies or non-peer-reviewed reports.[5 9–14] While delaying non-urgent scheduled surgeries was likely necessary to redirect healthcare resources to the surges of COVID-19 patients, the effect of this on surgical care during COVID-19 or the impact of delaying surgeries on patients, healthcare providers and the system is unknown. Nor is there evidence to support strategies to mitigate the consequences of these decisions.

The objective of this study was to understand the number of surgeries delayed or cancelled during COVID-19 and explore the consequences of delaying non-urgent surgeries on patients and the healthcare system.

METHODS

This study was conducted and reported in concordance with the Strengthening the Reporting of Observational Studies in Epidemiology and the Reporting of studies Conducted using Observational Routinely collected Data checklists.[15 16]

Study design and setting

This was a population-based retrospective cohort study conducted in Alberta, which has a population of 4.7 million.[17] Healthcare is publicly funded, with tertiary healthcare services delivered by Alberta Health Services, the single health data custodian. At the time of analysis and writing, the majority of scheduled surgeries occur in the over 22 publicly funded adult acute care hospitals in the province. The province is divided into five geographical health regions (zones); North, Edmonton, Calgary, Central and South.

Participants (cohort)

Adult patients (18 years and older) scheduled for surgery between 1 December 2018 and 31 December 2021 were included. Patients were identified through a record in the Operating Room Information Systems (ORIS), a provincial surgical registry for all patients in Alberta.[18] Patients are entered into the ORIS at the time they are consented for surgery. Patients who had data errors related to dates (eg, negative wait time or scheduled surgery date before decision to treat date), whose surgery date or last transaction date was outside of the study period, or whose surgery date was the same date as an emergency department visit date (ie, likely an urgent surgery) were excluded (online supplemental file 1).

Data sources, access, linkage and cleaning

The cohort was identified using ORIS and encounter-level data were deterministically linked to four data sources to obtain information about hospital stays, emergency room visits, physician visits and mortality using a unique provincial healthcare number (PHN). The Discharge Abstract Database (DAD) includes demographic, administrative, diagnostic and procedural data on all patients discharged from the hospital.[19–21] The National Ambulatory Care Recording System (NACRS) collects demographic, administrative, clinical and service-specific data from hospital-based and community-based ambulatory care visits, including day surgery, community outpatient clinic and emergency department visits.[22–24] Physician billing claims are used to bill the province of Alberta for physician services provided. Vital statistics include information about the date and cause of death.

These data sources were retrospectively abstracted in May 2022 by the data custodian (Alberta Health Services). Deidentified data (scrambled PHN) were provided to the principal investigator (KS). The range of data values, distribution and missing values were explored for all variables and data cleaning was performed by a trained data analyst (SV). A data enhancement strategy was used to deal with missing values.[25]

Outcomes & Variables

The primary outcomes were the proportion of surgeries completed and the wait time for surgery. Surgery status was a categorical variable with three levels—completed, waiting and cancelled reported in ORIS. The proportion of surgeries completed was the number of completed surgeries over the number of scheduled surgeries. Correspondingly, the proportion of surgeries cancelled or waiting was calculated as the number of surgeries cancelled or waiting over the number of scheduled surgeries.

For those who had surgery completed, the wait time was calculated as the difference between the date of surgery and the last ready-to-treat day (the date which was mutually agreeable to the patient and surgeon) in days. While the time from booking date to surgery date was available, we chose to include the last ready-to-treat date to take into considerations the wait time that was not due to healthcare system delays.

The secondary outcomes were healthcare resource use. In the absence of a single measure of healthcare resource use, cumulative length of hospital stay (total hospital length of stay for every hospital admission from DAD), the number of hospital readmissions (DAD), the number of emergency room visits (NACRS) and the number of physician visits (physician claims) were used to measure healthcare resource use.

Patient and surgery-related variables included patient age, sex, comorbidities (Charlson Comorbidity Index) and geographical zone at index surgery were abstracted from DAD, physician claims and ORIS. Patient's age and sex were obtained from ORIS. Comorbidities were calculated based on ICD-10-CA (International Classification of Disease, 10th Edition, Canada) codes in the DAD and ICD-9-CA codes in the physician claims database and were calculated using the Quan method.[26]

Surgical variables included the type of surgery (categorical variable in ORIS), cancer-related surgeries (dichotomous variables in ORIS), priority level (categorical variables in ORIS), and if COVID-19 was the reason for a change to the surgery date (string variable in ORIS). The type of surgery was determined by the most responsible healthcare provider and recorded in ORIS and was classified as cardiovascular, dentistry, gastrointestinal, general, neurology, obstetrics/gynaecology, ophthalmology, oral and maxillofacial, orthopaedic, otolaryngology, plastic, thoracic, transplant, urology, vascular and other. The recommended wait time was calculated using the Alberta Coding Access Targets for Surgery codes,[27] developed based on evidence-based best-practice guidelines for surgical care, to determine the priority for each surgery which was categorised as urgent priority (0–2 weeks), high priority (3–6 weeks), moderate priority (7–12 weeks) and lower priority (13+ weeks).

Time periods were created to explore the effects of the unique 'waves' of COVID-19 since there were strategic changes to surgical care during the study period. The time periods were defined as pre-COVID-19 (1 January 2018–29 February 2020), wave 1 (1 March 2020–22 August 2020), wave 2 (23 August 2020–20 March 2021), wave 3 (21 March 2021–17 July 2021), wave 4 (18 July 2021–31 December 2021). Surgeries were classified by the time period (wave) according to when they were booked for surgery.

Data analysis

The demographic characteristics of the cohorts were described using proportions, means (SD) and medians (IQR). One-way analysis of variance (ANOVA) for continuous variables, Kruskal-Wallis tests for skewed continuous variables and χ^2 tests for categorical variables were used to assess differences in the demographic characteristics, healthcare resource utilisation and safety pre-COVID-19 and across COVID-19 waves.

To examine the effect that patient characteristics had on the primary outcomes (surgery completed and wait time), regression models were used. Multivariable logistic regression was used to examine the effect of potential factors on having surgery completed during each wave of the COVID-19 pandemic (dichotomous; completed vs not completed) while multivariable quantile regression was used to identify factors associated with surgery wait time (continuous variable). Variable clustering was used for assessing collinearity and redundancy of candidate variables. Potential effect measure modifiers, confounder or predictor variables included patient sex, age, cancer status (cancer-related vs non-cancer-related surgeries), Charlson Comorbidity Index and type of surgeries. Potential interaction terms were included in the regression models to evaluate effect modification, and the models were adjusted for confounders. In addition, all potential interactions and confounders were extensively explored through data inspection (online supplemental file 1). Coefficients or ORs are presented with 95% CIs and are unadjusted unless indicated, and ANOVA plot was used to identify the largest effect size for each outcome.

All statistical analyses were conducted by using R software (V.4.2.3), and R packages rms[28] and ggplot2.[29]

Patient and public involvement

Patients and the public were not involved in the conception of this study, nor were they involved in data collection, analysis or interpretation of the findings.

RESULTS

Characteristics of the cohort

There were 202 470 unique patients with 259 677 scheduled surgeries (online supplemental file 2). The median age of patients was 59 years old, with the majority being female (55.5%, n=144 237), having surgery in the Edmonton zone (30.9%, n=80 215; table 1). The type of surgeries that were scheduled differed between the time periods; overall the most common type of surgery was general surgeries (25.7%, n=668 222), orthopaedic (19.7%, n=51 134) and ophthalmologic (16.5%, n=42 897) with the number of ophthalmological surgeries decreased during COVID-19 to 10.7% (n=3075) of surgeries (table 1). Similarly, the number of scheduled cancer surgeries increased from 10.4% (n=19 835) to 16.7% in the fourth wave of COVID-19 (n=4788, table 1).

Surgery status

Overall, 77.4% (n=201 061) of scheduled surgeries were completed in the cohort, 17.6% (n=45 591) were cancelled and 5.0% (n=13 025) were waiting (figure 1). The proportion of scheduled surgeries completed, cancelled and waiting changed throughout the COVID-19 pandemic (p<0.001). The proportion of surgeries that were completed remained stable until wave 4, where the proportion decreased to 67.0%. The number of surgeries that were waiting increased throughout the pandemic with a sharp increase in wave 4 to 17.1% (n=4902), and the number of surgeries cancelled remained stable except with a decrease (fewer surgeries cancelled) in wave 3 before returning to pre-COVID-19 levels in wave 4 (figure 1). Using logistic regression, geographical zone where the surgery was scheduled, the COVID-19 wave, the type of surgery, the priority level, whether it was a cancer surgery, patient age, sex and comorbidity were all associated with the surgery being completed. Patients who had lower priority dental or oral/maxillofacial surgery, scheduled in the two largest urban geographical zones, who were older with multimorbidity in wave 4 of COVID-19 had the lowest odds of having their surgery completed (online supplemental file 3). Using ANOVA, the priority level, type of surgery and geographical zone had the largest effect size (online supplemental file 3). When controlling for age, sex, geographical zone, cancer-related surgery and surgery type, the odds of having a surgery completed in wave 1 was 1.12 (95% CI 1.08 to 1.16), in wave 2 was 1.37 (95% CI 1.31 to 1.44), in wave

Table 1 Characteristics of the cohort

Variable	Cohort	Pre-COVID-19	Wave1	Wave2	Wave3	Wave4	P value
Scheduled surgeries	259677	115537	33648	52580	29229	28683	<0.001
Sex male (%)	115440 (44.5)	50532 (43.7)	15276 (45.4)	23702 (45.1)	12969 (44.4)	12961 (45.2)	<0.001
Age							
Median (IQR)	59.0 (43.0–70.0)	58.0 (43.0–70.0)	59.0 (43.0–70.0)	59.0 (43.0–70.0)	58.0 (43.0–69.0)	58.0 (43.0–69.0)	0.001
Mean (SD)	56.23 (17.0)	56.25 (17.1)	56.31 (17.0)	56.33 (17.0)	56.14 (16.9)	55.90 (16.8)	0.007
Comorbidities*							
Mean (SD)	0.51 (1.4)	0.53 (1.4)	0.55 (1.4)	0.49 (1.3)	0.48 (1.3)	0.45 (1.3)	<0.001
0	211447 (81.4)	93961 (81.3)	27040 (80.4)	42805 (81.4)	23928 (81.9)	23713 (82.7)	<0.001
1	15794 (6.1)	7126 (6.2)	2163 (6.4)	3305 (6.3)	1689 (5.8)	1511 (5.3)	
2+	32436 (12.5)	14450 (12.5)	4445 (13.2)	6470 (12.3)	3612 (12.4)	3459 (12.1)	
Surgery type							<0.001
Cardiovascular	4185 (1.6)	1144 (1.0)	758 (2.3)	973 (1.9)	593 (2.0)	717 (2.5)	
Dentistry	647 (0.2)	351 (0.3)	76 (0.2)	114 (0.2)	57 (0.2)	49 (0.2)	
Gastrointestinal	892 (0.3)	387 (0.3)	468 (1.4)	37 (0.1)	0 (0.0)	0 (0.0)	
General	668222 (25.7)	28440 (24.6)	8675 (25.8)	13591 (25.8)	7819 (26.8)	8297 (28.9)	
Neurology	4075 (1.6)	1753 (1.5)	524 (1.6)	774 (1.5)	509 (1.7)	515 (1.8)	
Obstetrics/gynaecology	35556 (13.7)	16008 (13.9)	4382 (13.0)	6848 (13.0)	4071 (13.9)	4247 (14.8)	
Ophthalmology	42897 (16.5)	21327 (18.5)	5255 (15.6)	8989 (17.1)	4251 (14.5)	3075 (10.7)	
Oral and maxillofacial	422 (0.2)	217 (0.2)	45 (0.1)	81 (0.2)	48 (0.2)	31 (0.1)	
Orthopaedic	51134 (19.7)	22316 (19.3)	6445 (19.2)	10647 (20.2)	6024 (20.6)	5702 (19.9)	
Other	202 (0.1)	8 (0.0)	8 (0.0)	29 (0.1)	41 (0.1)	116 (0.4)	
Otolaryngology	12934 (5.0)	5922 (5.1)	1531 (4.6)	2515 (4.8)	1397 (4.8)	1569 (5.5)	
Plastics	12576 (4.8)	5924 (5.1)	1684 (5.0)	2421 (4.6)	1385 (4.7)	1162 (4.1)	
Thoracic	815 (0.3)	362 (0.3)	112 (0.3)	174 (0.3)	69 (0.2)	98 (0.3)	
Transplant	295 (0.1)	110 (0.1)	40 (0.1)	55 (0.1)	31 (0.1)	59 (0.2)	
Urology	24430 (9.4)	10402 (9.0)	3436 (10.2)	4967 (9.4)	2754 (9.4)	2871 (10.0)	
Vascular	1795 (0.7)	866 (0.7)	209 (0.6)	365 (0.7)	180 (0.6)	175 (0.6)	
Cancer surgery	31501 (12.1)	12017 (10.4)	4327 (12.9)	6357 (12.1)	4012 (13.7)	4788 (16.7)	<0.001
Zone (%)							<0.001
Calgary	41262 (15.9)	19835 (17.2)	4681 (13.9)	7334 (13.9)	4985 (17.1)	4427 (15.4)	
Central	71546 (27.6)	31493 (27.3)	9407 (28.0)	15130 (28.8)	8003 (27.4)	7513 (26.2)	
Edmonton	80215 (30.9)	35070 (30.4)	11180 (33.2)	16013 (30.5)	8482 (29.0)	9470 (33.0)	
North	28991 (11.2)	12274 (10.6)	3637 (10.8)	6486 (12.3)	3484 (11.9)	3110 (10.8)	
South	37663 (14.5)	16865 (14.6)	4743 (14.1)	7617 (14.5)	4275 (14.6)	4163 (14.5)	

Pre-COVID-19 (1 January 2018–29 February 2020), wave 1 (1 March 2020–22 August 2020), wave 2 (23 August 2020–20 March 2021), wave 3 (21 March 2021–17 July 2021), wave 4 (18 July 2021–31 December 2021).
*Charlson Comorbidity Index calculated using all records.
n, number.

3 was 1.39 (95% CI 1.30 to 1.49), and in wave 4 was 1.03 (95% CI 0.94 to 1.12) compared with pre-COVID-19.

Wait time for surgery

For completed surgeries, the median wait time decreased from before COVID-19 across each COVID-19 wave (figure 2). The factors associated with the wait time were geographical zone, COVID-19 wave and the surgery type and priority (online supplemental file 3). Those who had their surgery in geographical zones outside the two major cities, who had a transplant, cardiovascular/vascular/thoracic surgery and were deemed a high priority had shorter wait times (online supplemental file 4). Using

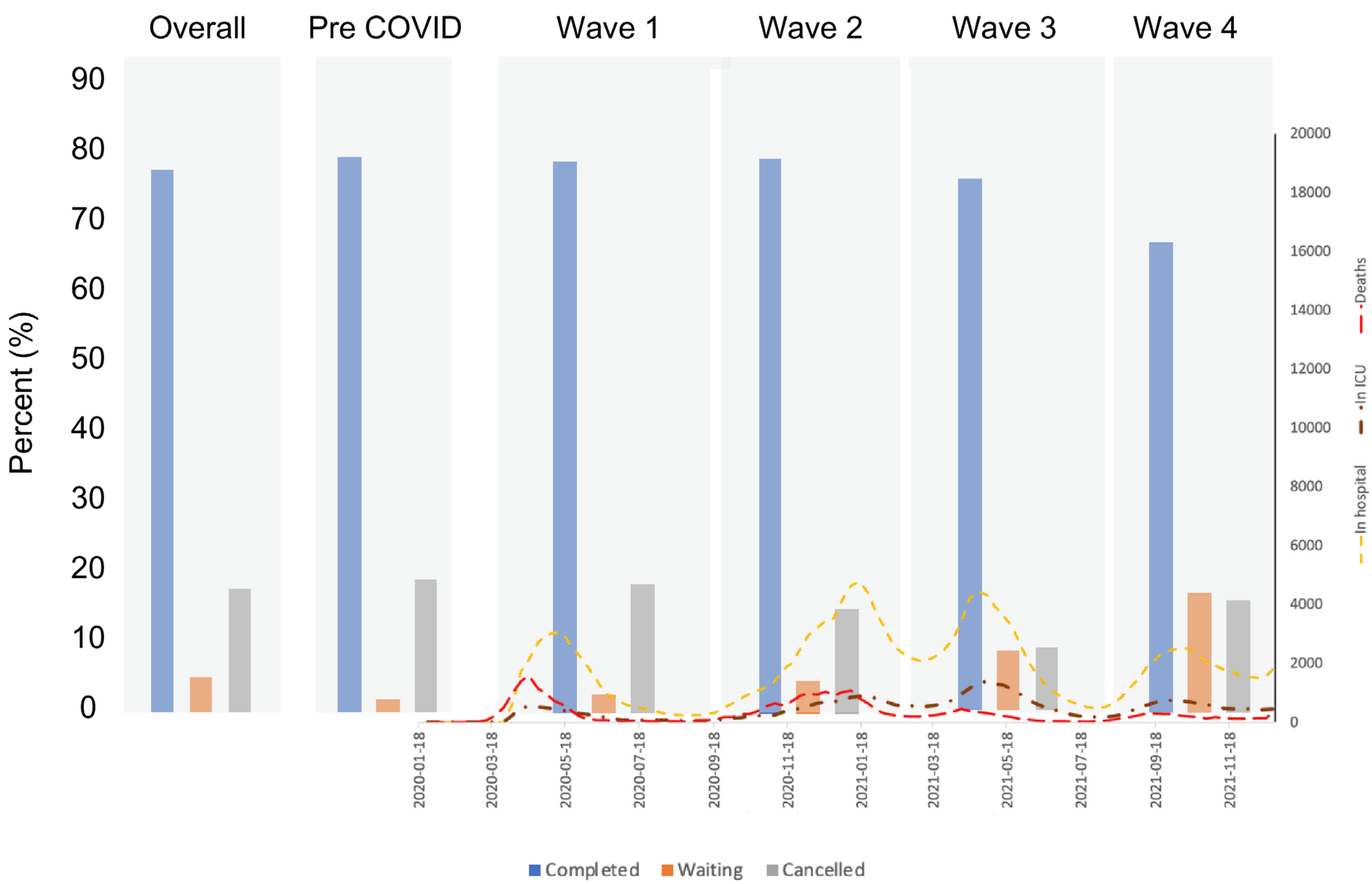

Figure 1 Surgery status by COVID-19 wave. ICU, intensive care unit.

ANOVA, the priority level, type of surgery and geographical zone had the largest effect size (online supplemental file 4).

The median wait time for scheduled surgery varied between the types of surgeries; ophthalmologic, oral and maxillofacial (and dentistry), and orthopaedic surgeries consistently had longer wait times but consistently decreased across COVID-19 waves ($p<0.0001$; figure 2). Wait time for cancer surgery remained relatively unchanged across time periods, with a small decrease in wait time during wave 1 compared with the other time periods (pre-COVID-19: median=5.71 weeks, IQR=3.14–11.85, wave 1: median=4.71 weeks, IQR=2.43–11.43, wave

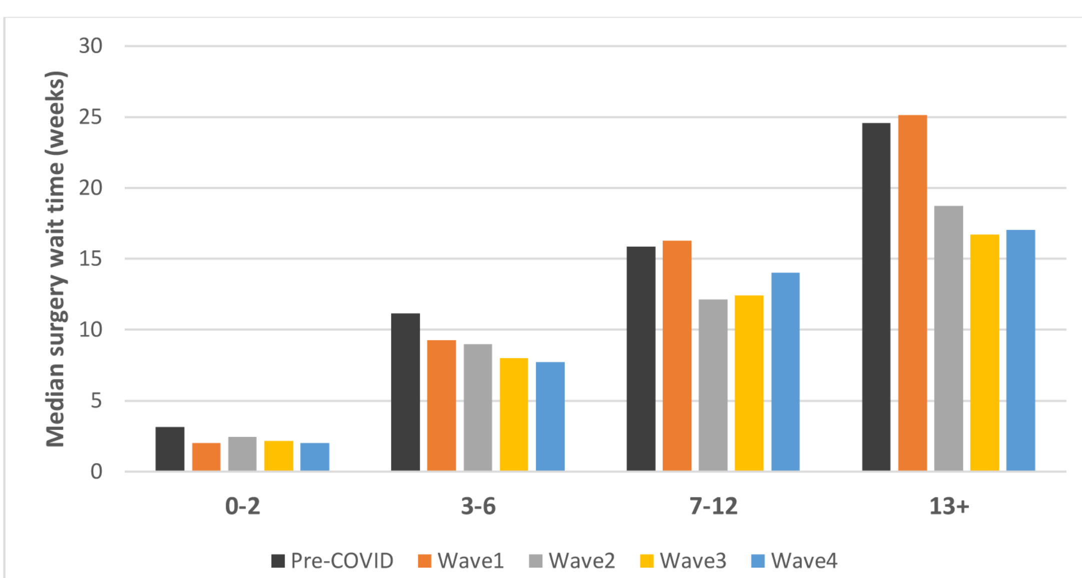

Figure 2 Median wait time by surgery and COVID-19 wave. Time periods are recommended time for type of surgery (0-2 weeks, 3-6 weeks, 7-12 weeks, 13+ weeks).

2: median=5.15 weeks, IQR=2.86–10.29, wave 3: 5.43 weeks, IQR=3.00–11.4, wave 4: 5.29 weeks, IQR=2.72–10.86; p<0.0001). The median surgery wait time for higher-priority surgeries was relatively unchanged, and the wait time for lower-priority surgeries decreased across COVID-19 waves (p<0.001).

When controlling for age, sex, geographical zone, cancer-related surgery and surgery type the geometric mean wait time in wave 1 was reduced by 5.8% (95% CI −7.4% to −4.2%), in wave 2 was reduced by 16.9% (95% CI −20.0% to −14.9%), in wave 3 was reduced by 18.8% (95% CI −21.8% to −15.9%), and in wave 4 was reduced by 22.1% (95% CI −25.8% to −18.4%) compared with the geometric mean wait time pre-COVID-19.

When examining surgeries that specifically were delayed due to COVID-19-related capacity issues, the median surgery wait time increased from 19.85 (IQR=10.82–38.43) weeks in wave 1 to 34.57 weeks (IQR=14.57–50.29) in wave 2, before decreasing to 28.29 (IQR=21.86–36.29) weeks in wave 3 and to 14.29 (IQR=9.29–21.29) weeks in wave 4 (p<0.001) for surgeries that were delayed due to COVID-19.

Healthcare resource use

Among patients scheduled for surgery, there were 155 687 hospital admissions among 113 023 unique patients during the study period, with the number of scheduled surgeries requiring hospital admission being lower before COVID-19 than during each wave of COVID-19 (table 2). However, the number of hospital admissions per patient admitted was lower during each wave of COVID-19 than before COVID-19 (table 2). While in the hospital, the number of ICU hours and, correspondingly, the resource intensity of patients was lower during all waves of COVID-19 than before COVID-19. The number of patients with an index hospital admission who was readmitted within 30 days was similar before COVID-19 and across all waves of COVID-19. The number of emergency room visits was similar across all waves of COVID-19 but was lower than before COVID-19. A similar pattern emerged when examining the number of physician visits; the number of physician visits per patient was similar across each wave of COVID-19 but went from 14.0 (IQR=8.00–23.00) before COVID-19 to 5.00 (3.00–10.00) in wave 1, 7.00 (IQR=4.00–13.00) in wave 2, 4.00 (IQR=2.00–8.00) in wave 3 and 5.00 (IQR=3.00–10.00) in wave 4.

Mortality

The number of patients who died while in hospital increased during COVID-19 compared with before COVID-19, with the highest proportion of hospital admissions resulting in death being in wave 4 (0.5% of hospital admissions died before COVID-19, 1.4% in wave 1, 1.8% in wave 2, 1.9% in wave 3 and 3.2% in wave 4, p<0.001). Overall all-cause mortality among patients scheduled for surgery also increased to 5.85% in wave 4 compared with 0.93% before COVID-19 (wave 1=2.74%, wave 2=2.96% and wave 3=3.26%).

DISCUSSION

In this study, while a larger proportion of scheduled surgeries were cancelled during many of the waves of COVID-19, the proportion of scheduled surgeries completed remained relatively stable until the fourth wave of COVID-19. The priority level of the surgery and the geographical zone were two of the strongest predictors of surgeries being completed, suggesting that COVID-19-related factors significantly contributed to surgeries being completed during COVID-19 and that some jurisdictions were more impacted than others, consistent with provincial trends in COVID-19 cases and hospitalisation.[30] For completed surgeries, the wait time decreased during COVID-19 and was associated with the priority level of the surgery, the type of surgery and the geographical zone where the surgery was scheduled. This finding is aligned with policies for surgical prioritisation during COVID-19 that outlined only high-priority surgeries, including cancer surgeries, were scheduled during some waves of COVID-19,[31] resulting in fewer surgeries of lower priority being scheduled, consequently reducing wait for surgery. Similarly, there was decreased healthcare resource use during COVID-19 and increased mortality.

During COVID-19, policies were enacted that prioritised cancer surgeries and high-priority surgeries among acutely ill patients.[31] These policies may have been drivers of surgeries being completed; COVID-19 wave, which may be a surrogate measure of surgical policies was one of the strongest predictors of wait times. These findings speak to the important role policy has in healthcare delivery. While this study was not designed to evaluate the effectiveness of policies for surgery during COVID-19, the findings suggest that policies that prioritised cancer surgery and other specific types of surgeries[3] resulted in more surgeries being completed and within clinically appropriate wait times. Additional research is needed to explore the appropriateness and effectiveness of policies for surgery during COVID-19. During COVID-19, many policies were implemented with little supporting evidence due to the novel nature of COVID-19 and the rapidly evolving situation; however, even outside of the pandemic, policies are not always evidence informed.[32 33] Incorporating evidence into health policy is critical and requires two key elements—having high-quality evidence to inform policy and approaches for incorporating evidence into policy. The growing body of evidence on surgical care during healthcare crises, generated since the beginning of the COVID-19 pandemic, can be used to inform surgical policies moving forward.[10 12 34 35] Strategies to strengthen evidence-informed health policy include better collaboration between health researchers and policy-makers; these symbiotic relationships and collaborative strategies should be established now so that during times of healthcare crisis urgent policies can be enacted.[36]

An important evidence-based consideration when developing policies to manage surgical wait times is the effect delays in surgery have on clinical outcomes. Delays

Table 2 Healthcare resource use

Variable	Pre-COVID-19		Wave 1		Wave 2		Wave 3		Wave 4		P value
	Crude	Adj*	Crude	Adj*	Crude	Adj*	Crude	Adj*	Crude	Adj*	Crude
Hospital visits† n (%)	61 089 (38.83)	123 785 (76.58)	23 733 (54.65)	33 265 (76.60)	31 290 (44.74)	53 956 (77.00)	18 840 (51.47)	28 477 (77.85)	20 735 (55.15)	29 013 (77.17)	
Hospital visits per patient Mean (SD)	1.52 (1.07)	1.47 (1.07)	1.29 (0.70)	1.41 (0.51)	1.33 (0.76)	1.35 (0.56)	1.25 (0.62)	129 (0.60)	1.31 (0.72)	1.24 (0.81)	<0.001
Hospital length of stay (days)‡ Median (IQR)§	26.00 (10.00–60.00)	10.18 (0.14)	14.00 (6.00–36.00)	12.26 (0.21)	19.00 (7.00–45.00)	11.53 (0.19)	12.00 (5.00–33.00)	12.65 (0.24)	15.00 (6.00–32.00)	12.86 (0.23)	<0.001
Resource intensity Median (IQR)	1.95 (1.09–3.60)	1.42 (0.01)	1.69 (0.98–3.21)	1.71 (0.01)	1.77 (1.04–3.41)	1.66 (0.01)	1.71 (0.92–3.30)	1.78 (0.01)	1.78 (1.02–3.30)	1.74 (0.01)	<0.001
ICU (hours)‡ Median (IQR)§	54.30 (8.20–127.10)	11.42 (0.41)	19.30 (0.00–70.70)	13.97 (0.60)	23.60 (0.00–91.65)	13.03 (0.53)	17.70 (0.00–68.50)	14.41 (0.66)	20.40 (0.00–80.35)	14.12 (0.66)	<0.001
Hospital readmission (30 days) Mean (SD)	528 (1.3)	563 (1.4)	309 (1.7)	257 (1.4)	300 (1.3)	306 (1.3)	219 (1.5)	211 (1.4)	201 (1.3)	221 (1.4)	<0.001
Emergency visits Total	231 674	229 357	75 244	74 491	93 419	92 484	57 661	57 084	74 187	73 445	
Emergency visits Median (IQR)¶	2.00 (1.00–3.00)	2.00	1.00 (1.00–2.00)	1.00	1.00 (1.00–2.00)	1.00	1.00 (1.00–2.00)	1.00	1.00 (1.00–2.00)	1.00	<0.001

*Adjusted for age at surgical admission, biological sex, Charlson Comorbidity Index, surgery type.
†Proportion of visits per scheduled surgeries.
‡Cumulative length of stay.
§Adjusted estimates include SD based on regression model.
¶Variance too low to report.
Adj, adjusted.

in having non-urgent surgeries within clinically appropriate time frames are associated with increases in undesirable outcomes, including mortality.[37 38] Indeed, we and others found that during COVID-19, there was an excess death rate (more observed deaths than expected) not attributed to COVID-19.[39 40] Some of these excess deaths may be partly attributable to delayed surgeries,[41] including those waiting to be scheduled for surgery which was not accounted for in this study resulting in an underestimate of the impact on patient health. Understanding the complex relationship between increased mortality and surgical delays was beyond the scope of this study. The impact of delaying non-urgent surgeries likely goes beyond mortality to patient quality of life, disease-specific outcomes, healthcare provider work satisfaction and wellness, and the healthcare system, as has been found during non-pandemic times.[13 42–48] Studies from our group found that patients and surgeons experienced many negative consequences related to delaying non-urgent surgeries during COVID-19.[5 49] Patients experienced a decrease in quality of life and included considerable distress while waiting for surgery during an uncertain time. Surgeons also experienced a great deal of distress, especially related to not being able to care for their patients to the best of their abilities but provided strategies to minimise the impact of caring for patients during times of healthcare constraint which should be considered.[49] These findings may extend beyond the pandemic as waiting for surgery persists.[5] Times of healthcare constraints continue in Canada and across the globe during the recovery from the wider impacts of COVID-19; future research is needed to understand the complex relationship between waiting longer than clinically recommended for surgery and outcomes beyond just survival and developing strategies to minimise the burden on patients, their healthcare providers and healthcare systems.

Access to healthcare is an important factor in wait times for surgery. The decrease in all measures of healthcare resource use suggests a decrease in access to healthcare, which has been corroborated by others.[50] It has been reported that patients avoided accessing the healthcare system because of a decrease in available health services, isolation measures and fear of contracting COVID-19.[51 52] The consequence of the decrease in healthcare resource use, including diagnostic services, may result in an impending surge in patients being diagnosed with illnesses such as cancer, consequently, there may be a surge in patients requiring surgical treatment for these illnesses.[8 53] Studies also suggest that this decrease in healthcare resource use will result in patients being diagnosed with more advanced disease states requiring more complex and invasive treatment.[54 55] The implications of the COVID-19 pandemic on the healthcare system and healthcare resource use will likely not be clear for some time. Continued epidemiological surveillance of disease and health services research into the evolving trends in healthcare resource use are needed to meet the healthcare needs of the population.

While this study has several strengths; population-based data across 3 years covering 1 year prior to COVID-19 and the four largest waves of COVID-19, limitations should be noted and considered. While our surgery data (ORIS) were rich and had many time-related variables, these data are not intended for research purposes and, therefore, are not regularly monitored for quality on a regular basis; indeed, there were some data entry errors noted and there were some missing dates which we were able to impute using variables in the other data sources (see figure 1). Additionally, exploring effect modifiers and confounders identified that surgery type was an effect measure modifier, however, due to the large number of categories and small sample sizes in some cells we were not able to present the stratified estimates in the main body of the paper for all effect measure modifiers; more research is needed to explore within surgery variance in more detail, as the type of surgery was an important factor in having surgery completed and the wait time for surgery. The present study likely underestimates the number of patients whose access to surgical care was compromised due to the COVID-19 pandemic because we were only able to include patients who had a surgery scheduled (entered into ORIS), which excludes a group of patients waiting for a referral to a surgeon. Similarly, with reduced operating room availability, surgeons were not able to schedule patients they knew required surgery. On a related note, we chose to use the time from the last ready-to-treat date to surgery date (wait 2) rather than time from booking to surgery which may have also underestimated the wait time to surgery. While leveraging routinely collected administrative health data was efficient, we could not measure outcomes related to quality of life and patient and healthcare provider experiences. However, our previous studies provide insight into the patient and healthcare provider experience during COVID-19.[5] Finally, generalisability of these findings beyond Alberta should be cautioned and factors such as a number of COVID-19 cases, hospitalisations and COVID-19-related public health measures including surgical policies should be considered when generalising these findings to other areas.

In conclusion, this study found modest changes in the proportion of surgeries completed throughout the first four waves of COVID-19 but no increase in wait times for completed surgeries. However, this should be interpreted with caution. Interestingly, there was a decrease in healthcare resource use and an increase in mortality during COVID-19. This suggests during times of healthcare constraint, patients may avoid seeking the healthcare they need, resulting in an increase in mortality, which may extend beyond the COVID-19 pandemic to times of healthcare constraint. Notably, the factors associated with having surgeries completed and waiting for surgery (COVID-19 wave, geographical location, surgery type and priority) are aligned with policies enacted during COVID-19 to prioritise surgical care for those with cancer or high-priority surgeries; future research should explore the effectiveness of these policies. This highlights the important role health policy plays in healthcare delivery and the need for evidence-informed policy through collaboration.

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Contributors KS was responsible for conceptualisation of the study design and methods, obtaining and maintaining the data, supervising data linkage, cleaning and analysis, contributed to the interpretation of the results, obtained funding for the study and drafted the manuscript. KS is responsible for the overall content as guarantor. SV was responsible for data cleaning and analysis and critically revised the manuscript. AT was responsible for data analysis and critically revised the manuscript. AGD'S provided critical assistance with data analysis and revisions to the manuscript. DAS provided critical assistance with data analysis and revisions to the manuscript. CE helped conceptualise the study and provided critically revisions to the manuscript. SI provided critical assistance with data analysis and revisions to the manuscript. AA helped conceptualise the data analysis plan and provided critical revisions to the manuscript. MB contributed to study conceptualisation and securing funding, contributed to interpretation of the results and provided critical revisions to the manuscript.

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REFERENCES

1. World Health Organization. Available: https://covid19.who.int/?gclid=EAIaIQobChMIt5Xu74WC7AIV3z2tBh2KngctEAAYASAAEgIRV_D_BwE
2. Prin M, Guglielminotti J, Mtalimanja O, *et al*. Emergency-to-elective surgery ratio: a global indicator of access to surgical care. *World J Surg* 2018;42:1971–80.
3. Ibadin S, Brindle M, Wasylak T, *et al*. Delivery and prioritization of surgical care in Canada during COVID-19: an environmental scan. *Int J Health Policy Manag* 2023;12:8007.
4. COVIDSurg Collaborative. Elective surgery cancellations due to the COVID-19 pandemic: global predictive modelling to inform surgical recovery plans. *Br J Surg* 2020;107:1440–9.
5. Sauro KM, Smith C, Kersen J, *et al*. The impact of delaying surgery during the COVID-19 pandemic in Alberta: a qualitative study. *CMAJ Open* 2023;11:E90–100.
6. Ciarleglio FA, Rigoni M, Mereu L, *et al*. The negative effects of COVID-19 and national lockdown on emergency surgery morbidity due to delayed access. *World J Emerg Surg* 2021;16:37.
7. Parmar A, Eskander A, Sander B, *et al*. Impact of cancer surgery slowdowns on patient survival during the COVID-19 pandemic: a microsimulation modelling study. *CMAJ* 2022;194:E408–14.
8. Eskander A, Li Q, Yu J, *et al*. Incident cancer detection during the COVID-19 pandemic. *J Natl Compr Canc Netw* 2022;20:276–84.
9. Canadian Institute for Health Information. CIHI's COVID-19 data and information. Ottawa, ON Canadian Institute for Health Information.
10. O'Rielly CM, Ng-Kamstra J, Kania-Richmond A, *et al*. Surgery & COVID-19: a rapid scoping review of the impact of COVID-19 on surgical services during public health emergencies. *BMJ Open* 2021;1:e043966.
11. Eskander A, Li Q, Hallet J, *et al*. Access to cancer surgery in a universal health care system during the COVID-19 pandemic. *JAMA Netw Open* 2021;4:e211104.
12. Wang J, Vahid S, Eberg M, *et al*. Clearing the surgical backlog caused by COVID-19 in Ontario: a time series modelling study. *CMAJ* 2020;192:E1347–56.
13. Forner D, Murnaghan S, Porter G, *et al*. Psychosocial distress in adult patients awaiting cancer surgery during the COVID-19 pandemic. *Curr Oncol* 2021;28:1867–78.
14. Canadian Institute for Health Information. Surgeries impacted by COVID-19: an update on volumes and wait times.
15. Elm E von, Altman DG, Egger M, *et al*. Strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *BMJ* 2007;335:806–8.
16. Benchimol EI, Smeeth L, Guttmann A, *et al*. The REporting of studies conducted using observational routinely-collected health data (RECORD) statement. *PLOS Med* 2015;12:e1001885.
17. Population statistics. Available: https://www.alberta.ca/population-statistics.aspx#population-estimates [accessed 5 Jul 2023]
18. Segall RE, Takata JL, Urbach DR. Wait-time reporting systems for elective surgery in Canada: a content analysis of provincial and territorial initiatives. *CMAJ Open* 2020;8:E844–51.
19. Canadian Institute for Health Information. Data quality documentation, discharge abstract database — current-year information, 2020–2021. 2021.
20. Canadian Institute for Health Information. DAD data elements 2021–2022. 2021.
21. Canadian Institute for Health Information. DAD abstracting manual. 2021.
22. Canadian Institute for Health Information. Data quality documentation, national ambulatory care reporting system — multi-year information. 2012.
23. Canadian Institute for Health Information. NACRS data elements 2021–2022. 2021.
24. Canadian Institute for Health Information. NACRS abstracting manual, 2021–2022. 2021.
25. Faris PD, Ghali WA, Brant R, *et al*. Multiple imputation versus data enhancement for dealing with missing data in observational health care outcome analyses. *J Clin Epidemiol* 2002;55:184–91.
26. Quan H, Sundararajan V, Halfon P, *et al*. Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data. *Med Care* 2005;43:1130–9.
27. Alberta coding access targets for surgery (ACATS) codes: alberta health services. n.d. Available: https://www.albertahealthservices.ca/scns/Page12961.aspx
28. Harrell F. Regression modeling strategies. 6.8-0 ed: R package. 2023.
29. Wickham H. ggplot2: Elegant graphics for data analysis. Cham: Springer; 2016. Available: http://link.springer.com/10.1007/978-3-319-24277-4
30. COVID tracker: centre for health informatics. n.d. Available: https://covid-tracker.chi-csm.ca/
31. Ibadin S, Brindle M, Wasylak T, *et al*. Surgical care in Canada during COVID-19: an environmental scan. *Int J Health Care Policy* 2023.
32. Malekinejad M, Horvath H, Snyder H, *et al*. The discordance between evidence and health policy in the United States: the science of translational research and the critical role of diverse stakeholders. *Health Res Policy Syst* 2018;16:81.
33. Orton L, Lloyd-Williams F, Taylor-Robinson D, *et al*. The use of research evidence in public health decision making processes: systematic review. *PLoS One* 2011;6:e21704.
34. Tolone S, Gambardella C, Brusciano L, *et al*. Telephonic triage before surgical ward admission and telemedicine during COVID-19 outbreak in Italy. Effective and easy procedures to reduce in-hospital positivity. *Int J Surg* 2020;78:123–5.

35 Zhen L, Lin T, Zhao ML, *et al*. Management strategy for the resumption of regular diagnosis and treatment in gastrointestinal surgery department during the outbreak of coronavirus disease 2019 (COVID-19). *Zhonghua Wei Chang Wai Ke Za Zhi* 2020;23:321–6.
36 Oliver K, Lorenc T, Innvær S. New directions in evidence-based policy research: a critical analysis of the literature. *Health Res Policy Syst* 2014;12:34.
37 McIsaac DI, Abdulla K, Yang H, *et al*. Association of delay of urgent or emergency surgery with mortality and use of health care resources: a propensity score–matched observational cohort study. *CMAJ* 2017;189:E905–12.
38 Pincus D, Ravi B, Wasserstein D, *et al*. Association between wait time and 30-day mortality in adults undergoing hip fracture surgery. *JAMA* 2017;318:1994–2003.
39 Appleby J. What is happening to non-covid deaths? *BMJ* 2020;369:m1607.
40 Beesoon S, Joffe MA, Bakal J, *et al*. Excess deaths during COVID-19 pandemic in Alberta, Canada. *Int J Infect Dis* 2022;116:S23.
41 Tam DY, Naimark D, Sander B, *et al*. COVID-19: predicting consequences of curtailing outpatient scheduled cardiac procedures in the face of COVID healthcare resource needs in Ontario. 2020.
42 Kulkarni GS, Urbach DR, Austin PC, *et al*. Longer wait times increase overall mortality in patients with bladder cancer. *J Urol* 2009;182:1318–24.
43 Ackerman IN, Graves SE, Wicks IP, *et al*. Severely compromised quality of life in women and those of lower socioeconomic status waiting for joint replacement surgery. *Arthritis Rheum* 2005;53:653–8.
44 Desmeules F, Dionne CE, Belzile E, *et al*. Waiting for total knee replacement surgery: factors associated with pain, stiffness, function and quality of life. *BMC Musculoskelet Disord* 2009;10:52.
45 Malik AT, Alexander JH, Li DD, *et al*. What are the costs of hip osteoarthritis in the year prior to a total hip arthroplasty? *J Arthroplasty* 2020;35:313–7.
46 Mascarenhas R. The Manitoba arthroplasty waiting list: impact on health-related quality of life and initiatives to remedy the problem. *J Eval Clin Pract* 2009;15:208–11.
47 Nikolova S, Harrison M, Sutton M. The impact of waiting time on health gains from surgery: evidence from a national patient-reported outcome dataset. *Health Econ* 2016;25:955–68.
48 Sommer JL, Jacobsohn E, El-Gabalawy R. Impacts of elective surgical cancellations and postponements in Canada. *Can J Anaesth* 2021;68:315–23.
49 Jaworska N, Schalm E, Kersen J, *et al*. The impact of delayed nonurgent surgery during the COVID-19 pandemic on surgeons in Alberta: a qualitative interview study. *CMAJ Open* 2023;11:E587–96.
50 Moynihan R, Sanders S, Michaleff ZA, *et al*. Impact of COVID-19 pandemic on utilisation of healthcare services: a systematic review. *BMJ Open* 2021;11:e045343.
51 Soares P, Leite A, Esteves S, *et al*. Factors associated with the patient's decision to avoid healthcare during the COVID-19 pandemic. *Int J Environ Res Public Health* 2021;18:13239.
52 Arnetz BB, Goetz C, vanSchagen J, *et al*. Patient-reported factors associated with avoidance of in-person care during the COVID-19 pandemic: results from a national survey. *PLOS ONE* 2022;17:e0272609.
53 Habbous S, Lambrinos A, Petersen S, *et al*. The effect of the COVID-19 pandemic on hospital admissions and outpatient visits in Ontario, Canada. *Ann Thorac Med* 2023;18:70–8.
54 Alshahrani MS, Alfaraj D, AlHumaid J, *et al*. Prevalence, causes, and adverse clinical impact of delayed presentation of non-COVID-19-related emergencies during the covid-19 pandemic: findings from a multicenter observational study. *Int J Environ Res Public Health* 2022;19:9818.
55 Maringe C, Spicer J, Morris M, *et al*. The impact of the COVID-19 pandemic on cancer deaths due to delays in diagnosis in England, UK: a national, population-based, modelling study. *Lancet Oncol* 2020;21:1023–34.