A Population-based Analysis of the COVID-19 Generated Surgical Backlog and Associated Emergency Department Presentations for Inguinal Hernias and Gallstone Disease

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Objective: To evaluate the downstream effects of the COVID-19 generated surgical backlog.

Background: Delayed elective surgeries may result in emergency department (ED) presentations and the need for urgent interventions.

Methods: Population-based repeated cross-sectional study utilizing administrative data. We quantified rates of elective cholecystectomy and inguinal hernia repair and rates of ED presentations, urgent interventions, and outcomes during the first and second waves of COVID-19 (March 1, 2020-February 28, 2021) as compared to a 3-year pre-COVID-19 period (January 1, 2017-February 29, 2020) in Ontario, Canada. Poisson generalized estimating equation models were used to predict expected rates during COVID-19 based on the pre-COVID-19 period. The ratio of observed (actual events) to expected rates was generated for surgical procedures (SRRs) and ED visits (ED-RRs).

Results: We identified 74,709 elective cholecystectomies and 60,038 elective inguinal hernia repairs. During the COVID-19 period, elective inguinal hernia repairs decreased by 21% (SRR 0.791; 0.760–0.824) whereas elective cholecystectomies decreased by 23% (SRR 0.773; 0.732–0.816). ED visits for inguinal hernia decreased by 17% (ED-RR 0.829; 0.786 - 0.874) whereas ED visits for gallstones decreased by 8% (ED-RR 0.922; 0.878 - 0.967). A higher population rate of urgent cholecystectomy was observed, particularly after the first wave (SRR 1.076; 1.000–1.158). No difference was seen in inguinal hernias.

Conclusions: An over 20% reduction in elective surgeries and an increase in urgent cholecystectomies was observed during the COVID-19 period suggesting a rebound effect secondary to the surgical backlog. The COVID-19 generated surgical backlog will have a heterogeneous downstream effect with significant implications for surgical recovery planning.

Keywords: COVID, COVID-19, elective surgery, gallstone, inguinal hernia, surgical backlog

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Elective surgery has been profoundly affected by the COVID-19 pandemic. The COVIDSurg Collaborative estimated over 28 million elective surgeries were delayed or postponed worldwide during the first 12 weeks of the pandemic.[1] The Centers for Medicare & Medicaid Services in the United States recommended delays in "nonessential" surgeries on March 18, 2020.[2] Michigan instituted a government-directed slowdown during the first wave of COVID-19 which generated a large surgical backlog.[3] Subsequent COVID-19 waves have led to additional government-mandated surgical slowdowns with varying impact across the United States.[3,4]

One of the goals of elective surgery is to prevent disease progression that may result in emergency department (ED) presentations and the need for urgent interventions. Such is the case for inguinal hernia repair and cholecystectomy where incarcerated hernias or complicated gallstone disease (ie, cholecystitis, gallstone pancreatitis, choledocolithiasis) may be the consequence of delayed elective care. To evaluate the downstream effects of the COVID-19 generated surgical backlog, we quantified population-based rates of elective cholecystectomy and inguinal hernia repair during the first and second waves of COVID-19 in Ontario, Canada as compared to a 3-year pre- COVID-19 baseline period. We then determined if there was a difference in rates of ED presentations, urgent interventions, and associated outcomes for symptomatic inguinal hernias and gallstone disease.

METHODS

Setting and Study Design

We conducted a population-based repeated cross-sectional study utilizing linked health administrative data held at Institute for Clinical Evaluative Sciences (ICES) which is authorized to collect and use health care data for the purposes of health system analysis, evaluation, and decision support. Secure access to these data is governed by policies and procedures that are approved by the Information and Privacy Commissioner of Ontario, Canada. We included adults residing in Ontario who underwent either an elective inguinal hernia repair, elective cholecystectomy, or presented to the ED with an inguinal hernia or gallstone disease diagnosis between January 1, 2017 and February 28, 2021. The universally accessible, single-payer healthcare system in Ontario allowed for the capture of all elective surgery, ED visits, and hospital admissions.

Data Sources

The Canadian Institute for Health Information National Ambulatory Care Reporting System (NACRS) captures demographic, diagnostic, procedural, and discharge data for all ED visits in Ontario. The Discharge Abstract Database (Canadian Institute for Health Information-Discharge Abstract Database) captures similar data for all acute care hospitalizations. The NACRS Same Day Surgery database captures diagnostic and procedural data for all ambulatory surgeries. The Registered Persons Database is a vital statistics registry that contains demographic data for all Ontario residents eligible for care under the Ontario Health Insurance Plan. Registered Persons Database eligibility files were used to determine population counts and person-weeks at risk. ICES derived validated cohorts were used to characterize patient comorbidities.[5] These datasets were linked using unique encoded identifiers and analyzed at ICES. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines were followed (Appendix A, http://links.lww.com/SLA/D665).

Time Periods

A government-mandated abrupt cancellation of elective surgery in Ontario, Canada occurred on March 15, 2020.[6] This directive was associated with an over 80% decrease in the number of elective procedures performed in the weeks following this mandate compared to the equivalent weeks in 2019. Although this directive was limited to elective procedures, an unexpected and similar trend was observed for urgent surgical procedures (SRRs).[7] A gradual reopening of elective surgery in Ontario commenced on May 26, 2020.[8]

March 1, 2020 defined the start of the ''COVID-19 period.'' This period was further divided into a ''first wave'' (March 1-June 30, 2020), ''intervening period'' (July 1-October 1, 2020), and a ''second wave'' (October 2, 2020-February 27, 2021) based on the nadir in COVID-19 hospitalizations observed between waves. We evaluated differences across each period as public perception and the healthcare system adapted to COVID-19 over time. The pre-COVID-19 baseline period spanned January 1, 2017 to February 29, 2020).

Study Population – Elective Surgeries

Elective procedures were defined as either ambulatory or planned procedures requiring admission to hospital. We excluded those not residing in Ontario and those who were ineligible for Ontario Health Insurance Plan. Procedures were identified using the Canadian Classification of Health Interventions system, which is an alphanumeric coding system, designed to capture details on the type of intervention performed (Appendix B, http://links.lww.com/SLA/D665). Weekly rates of elective procedures per 1000 persons were generated for each procedure, by age group and sex, using the corresponding population on January 1st of each year as the denominator for rates as it did not change significantly over the year.

Study Population – Urgent Presentations, Interventions, Outcomes

To evaluate whether a change in elective inguinal hernia and cholecystectomy procedures during the COVID-19 period was associated with an increase in urgent presentations to the ED, need for urgent interventions, and outcomes, we identified adult patients who presented during the study period with symptomatic inguinal hernias or symptomatic gallstone disease, defined as: biliary colic, cholecystitis, gallstone pancreatitis, or common bile duct stones. Diagnoses were identified using International Statistical Classification of Diseases and Related Health Problems, 10th Revision Canada main presenting diagnosis codes (Appendix C, http://links.lww.com/SLA/D665) in NACRS. Weekly rates of ED visits per 1000 persons were generated for each condition.

For each patient presenting to the ED we ascertained age, sex, neighborhood income quintile,[9] rurality,[10] comorbidities, time of presentation [after-hours (5 PM-7 AM) and/or weekend (Saturday, Sunday, statutory holidays)], hospitalization after index ED visit, length of hospital stay, and in-hospital mortality. In addition, urgent management strategies that encompass the breath of possible endoscopic, surgical, and image-guided management were identified for each condition (Appendix D, http://links.lww.com/SLA/D665).

Statistical Analysis

Data from the pre-COVID-19 baseline period were used to estimate the pre-COVID-19 predicted monthly rate for each type of event (ie, surgeries or ED presentations) that would have occurred during the COVID-19 period had the pandemic not occurred. We utilized similar analytic methods to our work for the SARS pandemic[11] using a long baseline period to stabilize the prepandemic estimates and control for monthly fluctuations. Poisson generalized estimating equation models for clustered count data was used to model the pre- COVID-19 trend to predict expected post-COVID-19 trends in the absence of restrictions. The unit of analysis was the age group-sex- month stratum. The dependent variable was the stratum-specific count to the population in the stratum; the offset used was the log of the stratum-specific population. The working correlation structure was first-order autoregressive, autocorrelation with a lag of 1, to account for any monthly surges not accounted for by average month effects. Pre- COVID-19 models included age group-sex interactions, a secular time trend, and pre-COVID-19 month effects to model seasonal variations with April as the reference month. Pre-COVID-19 model coefficients were applied to the post-COVID-19 age-sex-month strata to obtain expected post-COVID-19 age-sex-month-specific rates and confidence intervals in the absence of restrictions.

The surgical backlog was defined as the difference between the observed monthly rates of surgeries during the COVID-19 period and the expected numbers based on the pre-COVID-19 trends.[11] We computed the expected post-COVID-19 rates and confidence intervals by applying the linear combination of pre-COVID-19 regression coefficients to the post-COVID-19 age-sex-month strata and exponentiating these values. The relative change in post-COVID-19 rates was expressed as the ratio of observed to expected rates by exponentiating the difference of observed and expected post-COVID-19 log rates and confidence intervals. These rate ratios were generated for elective and urgent SRRs and ED visits (ED-RRs). We identified periods where the backlog was increasing (surgical volumes were below predicted, upper confidence limit below 1.00) and periods of surgical recovery (surgical volumes were above predicted, lower confidence limit above 1.00). Similarly, the ED-RR allowed us to characterize urgent presentations as above or below predicted. Rate ratios were produced for every month of the COVID-19 period, for wave 1, intervening period, and wave 2, and for the overall COVID-19 period.

Baseline patient characteristics were compared using standardized differences. Standardized differences of $<10\%$ represent minimal imbalance.[12] Secondary outcomes were evaluated using the chi- squared and Kruskal-Wallis nonparametric tests where appropriate.

RESULTS

There were 134,747 elective procedures during the study period (55% cholecystectomies n = 74,709; 45% inguinal hernia repairs n = 60,038). Secondary to government directives to ramp down scheduled surgeries on March 15, 2020, there was an abrupt and sustained decrease in the observed rate for both procedures (Fig. 1A-C).

Elective inguinal hernia repairs decreased by 71% in wave 1 (SRR 0.289; 0.282–0.297), with the largest decreases seen during April 2020 (SRR 0.020; 0.019–0.020), and May 2020 (SRR 0.104; 0.101–0.107). However, the backlog continued to grow in June 2020 (SRR 0.557; 0.534–0.581) despite lifting of the mandated surgical slowdown on May 26, 2020. The intervening period, where COVID-19 hospitalizations were at their lowest and there was no surgical slowdown, exhibited a period of sustained surgical recovery (SRR

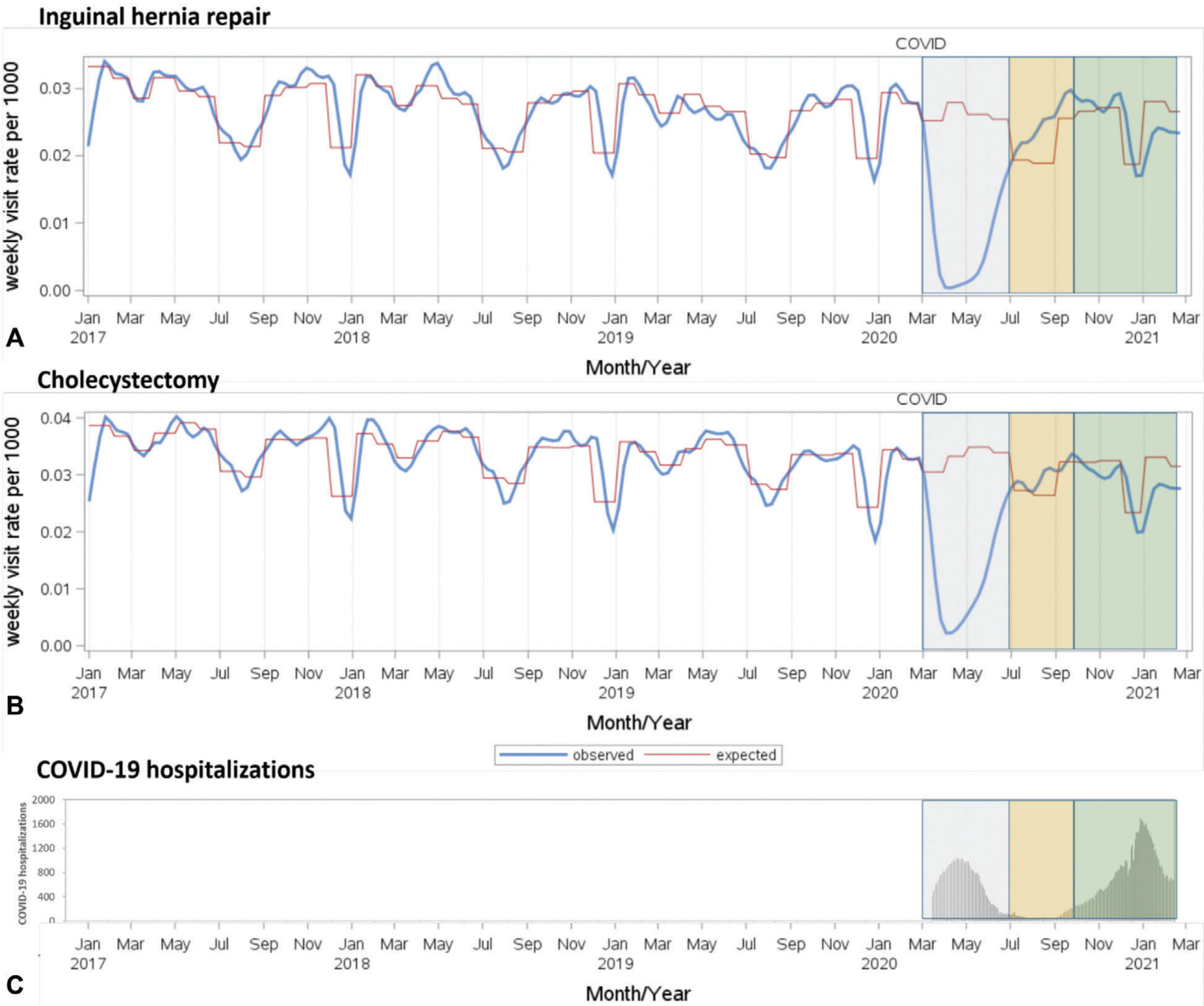

FIGURE 1. Figures show the observed (blue line) and expected rate (red line) of elective procedures (Fig. 1), emergency department visits (Fig. 2), and urgent procedures (Fig. 3). The expected rate was derived from Poisson generalized estimating equation models for clustered count data. The 3-year pre-COVID-19 baseline period (January 1,2017–February 27, 2020) and the COVID-19 period (March 1, 2020-February 28, 2021) are shown. The COVID-19 period was further divided into a ''first wave'' (March 1 -June 30, 2020, shown as a blue shaded area), ''intervening period'' (July 1–October 1, 2020, shown as a yellow shaded area), and a ''second wave'' (October 2, 2020-February 27, 2021, shown as a green shaded area) based on the nadir in COVID-19 hospitalizations observed between waves. The number of COVID-19 hospitalizations in the first wave, intervening period, and second wave are shown in Figure 1C.

1.185; 1.150 - 1.22), equivalent to 18% higher volume compared the 3-year baseline period. Wave 2 (SRR 0.967; 0.916–1.021) saw a return to historical volumes from October through December; however, the surgical backlog again began to grow in the months of January 2021 (SRR 0.873; 0.863–0.883) and February 2021 (SRR 0.866; 0.832–0.901), coinciding with the peak of the second wave of COVID-19 in Ontario (Fig. 1A-C). No governmental directives to ramp down surgical care were in force at that time. The entire CoVlD-19 period (March 2020-February 2021) saw a 21% decrease in elective inguinal hernia repairs (SRR 0.791; 0.760–0.824), equivalent to 3517 fewer procedures performed.

Elective cholecystectomies decreased by 61% (SRR 0.388; 0.368–0.410) during wave 1 with below expected volumes from March through June 2020. The intervening period exhibited a return to expected volumes (SRR 1.065; 0.999–1.137) with surgical recovery only seen in August 2020 (SRR 1.132; 1.071–1.196). Elective cholecystectomies decreased by 8% in wave 2 (SRR 0.913; 0.871- 0.957), with periods of increasing surgical backlog observed during November 2020 (SRR 0.916; 0.892–0.942), December 2020 (SRR 0.940; 0.889–0.994), January 2021 (SRR 0.851; 0.815–0.890), and February 2021 (SRR 0.876; 0.816–0.941) of 2021 (Fig. 1B and C). The entire COVID-19 period (March 2020-February 2021) saw a 23% decrease in elective cholecystectomies (SRR 0.773; 0.7320.816) compared to the 3-year pre-COVID-19 baseline period, equivalent to 4,580 fewer procedures.

Urgent Presentations and Interventions

There were 102,632 ED presentations during the study period (78% gallstone disease n = 79,459; 22% inguinal hernia n = 23,173). Baseline characteristics of patients presenting to the ED were similar between study periods for both symptomatic inguinal hernias and gallstone disease respectively (Table 1 - Supplement, http://links.lww.com/SLA/D665). During the entire study period, 48.1% (n = 49,400) of patients were admitted to hospital; admission rate varied by condition, from 16.1% (n = 3724) for symptomatic inguinal hernia to 57.4% (n = 45,676) for gallstone disease. Three out of 4 admitted patients required a surgical, endoscopic, or image-guided intervention (73%, n = 33,353 for gallstone disease; 75.1%, n = 2798 for inguinal hernia) (Table 2 - Supplement, http://links.lww.com/SLA/D665).

Sharp decreases in ED presentations coinciding with the start of the first wave of the COVID-19 period were seen for both inguinal hernia and gallstone disease (Fig. 2). ED visits for inguinal hernias were 21% below expected volumes in wave 1 (ED-RR 0.790; 0.738–0.845), 5.7% below expected in the intervening period (ED-RR 0.943; 0.908–0.980), and 18.9% below expected in wave 2 (ED-RR 0.811; 0.744–0.850). There were no months during the COVID-19 period with above expected volumes of ED presentations for inguinal hernia (Fig. 2A). The entire COVID-19 period (ED-RR 0.829; 0.786–0.874) saw a 17% decrease in ED presentations compared to the 3-year baseline period, equivalent to 1049 fewer presentations for inguinal hernias in the ED. There were no differences in time of ED presentation, need for hospitalization, overall frequency or type of urgent intervention (ie, bowel resection), length of stay, and in-hospital mortality across study periods for symptomatic inguinal hernias (Table 2 – Supplement, http://links.lww.com/SLA/D665). Wave 1 exhibited below expected volumes of urgent inguinal hernia repairs (SRR 0.801; 0.716–0.896), while the intervening period (SRR 1.042; 0.971–1.119) and wave 2 (SRR 0.879; 0.731–1.057) saw a return to expected urgent inguinal hernia repairs compared to the 3-year baseline period (Fig. 3A). Above expected volumes of urgent inguinal hernia repairs were only seen in July 2020 (SRR 1.090; 1.001–1.187) and August 2020 (SRR 1.180; 1.090–1.276). Overall volumes of urgent inguinal hernia repairs were similar to the 3-year baseline COVID-19 period (SRR 0.892; 0.776–1.026).

ED visits for gallstone disease were 8% below expected in the entire COVID-19 period (ED-RR 0.922; 0.878–0.967) compared to the 3-year pre-COVID-19 baseline period, equivalent to 1569 fewer ED visits. Below expected volumes were only seen during wave 1 (ED-RR 0.842; 0.802–0.883) and ED visits returned to expected volumes during the intervening period (ED-RR 0.985; 0.961–1.010) and wave 2 (ED-RR 0.955; 0.901–1.013). There were no months with above expected volumes of ED presentations for gallstone disease (Fig. 2B). In contrast to inguinal hernias, patients presenting with gallstone disease during the COVID-19 period were more likely to be admitted to hospital and had a higher rate of urgent interventions compared to the 3-year pre-COVID-19 baseline period. This difference was driven by a higher population rate of urgent cholecystectomies during the intervening period and wave 2; the number of ERCP and cholecystostomies remained stable across study periods (Table 2 – Supplement, http://links.lww.com/SLA/D665). Overall volumes of urgent cholecystectomies were similar compared to the 3year baseline period (SRR 1.041; 0.978–1.108). Urgent cholecystectomies were only below expected volumes during the first 2 months of wave 1 [March 2020 (SRR 0.795; 0.736–0.859), April 2020 (SRR 0.864; 0.814–0.918), overall wave 1 (SRR 0.970; 0.912–1.131)]. Urgent cholecystectomies were above expected

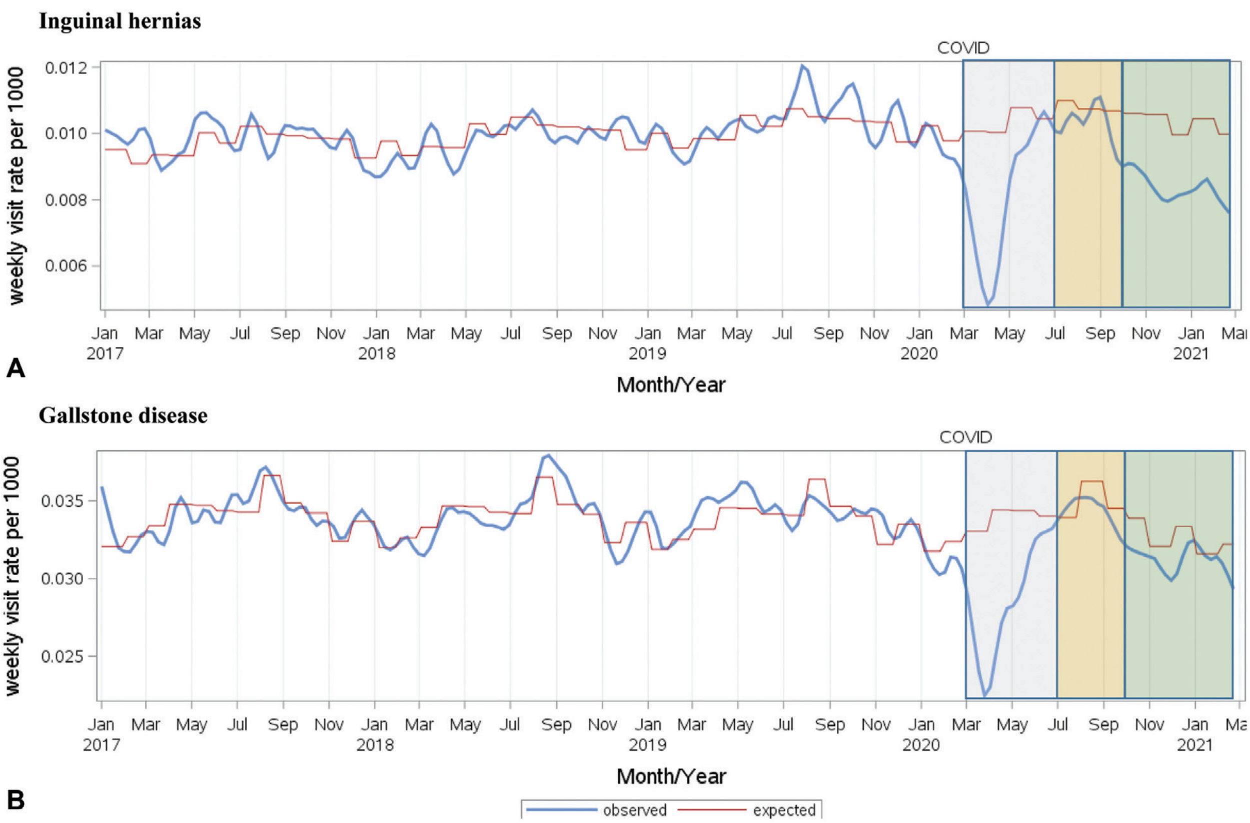

FIGURE 2. Observed and expected rates of emergency department visits for inguinal hernias and gallstone disease.

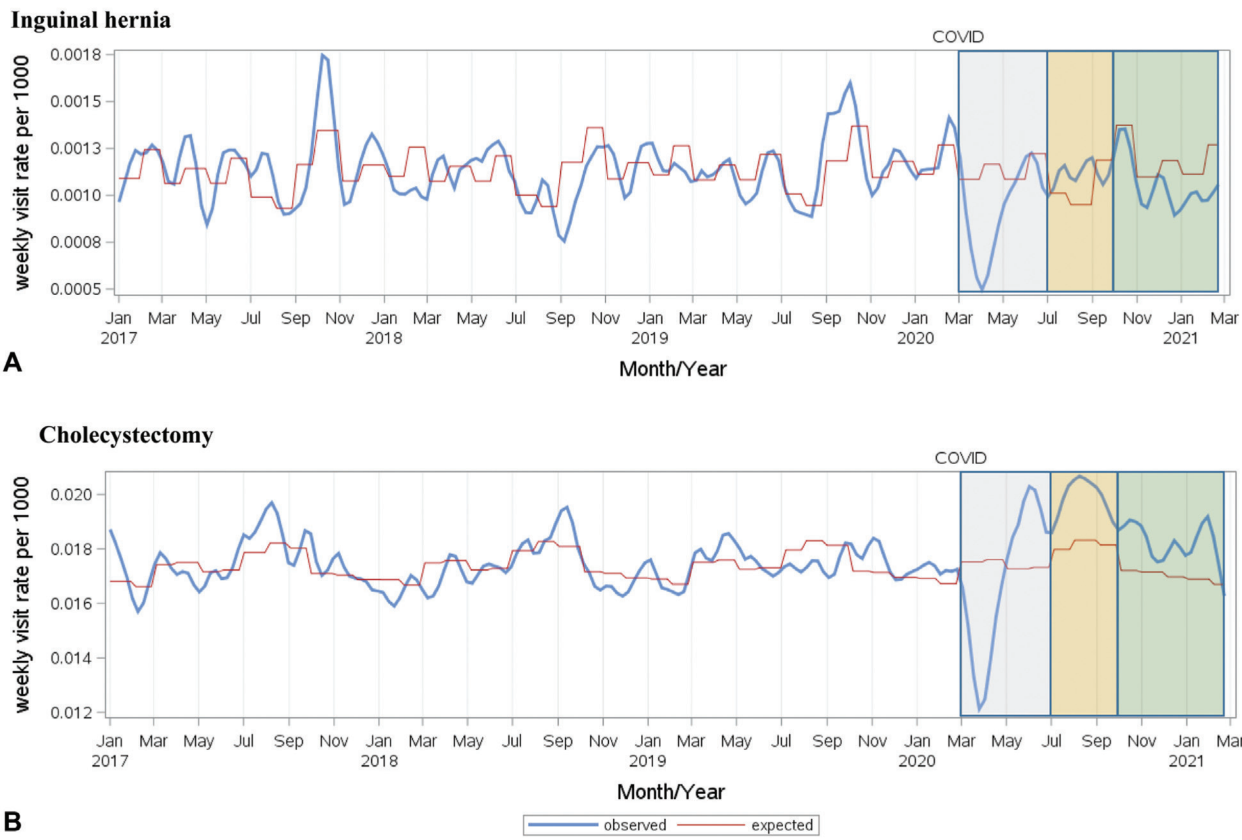

FIGURE 3. Observed and predicted rates of urgent inguinal hernia repairs and cholecystectomies.

volumes during the intervening period (SRR 1.093; 1.049–1.139) and wave 2 (SRR 1.076; 1.000–1.158) (Fig. 3B). There was no difference in length of hospital stay and in-hospital mortality across study periods.

DISCUSSION

This study has 3 key findings. First, the magnitude of the COVID-19 generated surgical backlog is substantial as there were 21% fewer elective inguinal hernia repairs (n = 3517) and 23% fewer cholecystectomies (n = 4580) performed during the COVID-19 period compared to a 3-year pre-COVID-19 baseline period. Backlog growth was most pronounced during the government mandated surgical slowdown in wave 1. This reached a nadir in April 2020, with 2% and 8% of the typical volume of elective cases occurring for inguinal hernias and cholecystectomies, respectively. However, backlogs continued to grow particularly during the peak of the second COVID-19 wave despite the absence of governmental directives to halt elective surgery. We observed limited capacity for the system to over perform. Surgical recovery was only observed during the intervening period and a sustained period of recovery was only seen for inguinal hernias. These findings confirm surgical recovery will occur slowly even in the absence of high COVID-19 inpatient load, and require an extended period of operating above standard surgical volumes.[13,14]

Second, we did not identify an increase in ED presentations for inguinal hernias or gallstone disease as a result of the backlog. Conversely, there was evidence of ED avoidance, being most marked during the first wave. Although ED volumes returned to normal for a brief period, a decrease in presentations was once again observed during the second wave and was particularly prominent for inguinal hernias. This finding is in keeping with several other studies examining emergency general surgery presentations during the COVID-19 pandemic, and likely reflects avoidance of hospitals and the ED when levels of COVID-19 infectivity are high.[15–17] It is possible that an alternative explanation exists for the decrease in observed ED events, such as a true decrease in the incidence of urgent and emergent disease as a result of environmental and behavioral changes or an increase in virtual visits for lower severity presentations; however, this is unlikely to account for all the differences observed.

Lastly, there were no clinically-important differences in outcomes during the COVID-19 period for patients presenting to the ED with inguinal hernias during the period of observation. We would expect that, if patients were delaying treatment for urgent and emergent conditions, or self-selecting for only life-threatening complications of disease, that we would observe worsened outcomes and higher rates of operative intervention in those presenting to the ED, neither of which was demonstrated in inguinal hernias. Additionally, the volume of urgent inguinal hernia repair remained at or below expected for all except 2 months immediately after the first wave. This lends further support to the absence of a significant ‘‘rebound period.’’ These findings are in contrast to those for gallstone disease where a higher rate of urgent cholecystectomy was observed compared to the baseline period. The rate of urgent procedures performed was above expected for nearly every month examined. A ‘‘rebound effect’’ is suggested in which, after the initial decrease in urgent procedures and large decrease in elective procedure volume, we see many months of increased urgent cholecystectomy. Our findings though are reassuring. Although a higher proportion of patients with ED presentations for gallstone disease were admitted to hospital and a higher proportion underwent an urgent intervention, there was no increase in open surgery or use of cholecystostomy tubes, no increase in length of stay, and no increase in mortality. The system was able to manage the increased urgent operative load with outcomes equivalent to the prepandemic era.

Large scale disruptions of local or regional healthcare systems are not infrequent. Natural disasters, transportation events, and terrorism are associated with mass casualty incidents that can overwhelm local resources for a period of time. Disaster preparedness protocols are designed to address surge and include cancelation of elective surgery but rely on rapid subsequent return to preevent capacity. The COVID-19 pandemic, however, was associated with a global and sustained disruption of healthcare delivery that required an unprecedented government mandated surgical slowdown which was commonly implemented across an entire region despite varying COVID-19 loads within the region. Blunt public health instruments, like region-wide government mandated surgical slowdowns, create unused capacity within a system and can further worsen pandemic-driven surgical backlogs. Response to the next global pandemic should be based on a system as a whole approach in where acute care beds, surgical capacity, and critical care beds are used as a regional resource with pro-active patient transfers that avoid local system collapse. This targeted approach was successfully implemented in Ontario, Canada during the third COVID-19 wave.[18]

Strengths and Limitations

The major strengths of this study include the populationbased nature of the data sources which allowed for large sample sizes and the ascertainment of complete outcomes. There are limitations in this study that are inherent to the datasets available at ICES. We are unable to ascertain whether patients that presented to the ED had delayed or canceled elective procedures. We are also unable to determine whether the rate of virtual or inperson outpatient clinic appointments changed during the study period. Increased use of virtual visits may have facilitated safe delivery of care outside the ED for biliary colic or symptomatic hernias without incarceration or strangulation. Furthermore, the outcomes of delayed elective care, particularly for inguinal hernias, may only become apparent with longer periods of observation given the low rates of incarceration and strangulation. Despite this, the use of a long, 3-year baseline period, and inclusion of a population-level assessment of ED visits and elective and urgent procedures is expected to capture nearly all clinical encounters important to the analysis of the urgent care of these disorders. Differences observed reflect changes in how all patients in the region accessed elective and urgent surgical care during the COVID-19 period.

CONCLUSIONS

The COVID-19 period was associated with an over 20% reduction in the volume of elective inguinal hernia repairs and cholecystectomies. The substantial COVID-19 generated surgical backlog was not associated with an increase in subsequent ED visits for either inguinal hernias or gallstone disease. However, a consistent increase in the population rate of urgent cholecystectomies was observed, suggesting a rebound effect secondary to the large surgical backlog. The COVID-19 generated surgical backlog will have a heterogeneous downstream effect across different elective surgeries with significant implications for surgical recovery planning.

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