Acute health care use among children during the first 2.5 years of the COVID-19 pandemic in Ontario, Canada: a population-based repeated cross-sectional study

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Abstract

Background: The effects of the decline in health care use at the start of the COVID-19 pandemic on the health of children are unclear. We sought to estimate changes in rates of severe and potentially preventable health outcomes among children during the pandemic.

Methods: We conducted a repeated cross-sectional study of children aged 0–17 years using linked population health administrative and disease registry data from January 2017 through August 2022 in Ontario, Canada. We compared observed rates of emergency department visits and hospital admissions during the pandemic to predicted rates based on the 3 years preceding the pandemic. We evaluated outcomes among children and neonates overall, among children with chronic health conditions and among children with specific diseases sensitive to delays in care.

Results: All acute care use for children decreased immediately at the onset of the pandemic, reaching its lowest rate in April 2020 for emergency department visits (adjusted relative rate [RR] 0.28, 95% confidence interval [CI] 0.28–0.29) and hospital admissions (adjusted RR 0.43, 95% CI 0.42–0.44). These decreases were sustained until September 2021 and May 2022, respectively. During the pandemic overall, rates of all-cause mortality, admissions for ambulatory care–sensitive conditions, newborn readmissions or emergency department visits or hospital admissions among children with chronic health conditions did not exceed predicted rates. However, after declining significantly between March and May 2020, new presentations of diabetes mellitus increased significantly during most of 2021 (peak adjusted RR 1.49, 95% CI 1.28–1.74 in July 2021) and much of 2022. Among these children, presentations for diabetic ketoacidosis were significantly higher than expected during the pandemic overall (adjusted RR 1.14, 95% CI 1.00–1.30). We observed similar time trends for new presentations of cancer, but we observed no excess presentations of severe cancer overall (adjusted RR 0.91, 95% CI 0.62–1.34).

Interpretation: In the first 30 months of the pandemic, disruptions to care were associated with important delays in new diagnoses of diabetes but not with other acute presentations of select preventable conditions or with mortality. Mitigation strategies in future pandemics or other health system disruptions should include education campaigns around important symptoms in children that require medical attention.

Although the direct impact of COVID-19 on children has been less severe than among adults, the indirect effect of the pandemic related to deferred care may confer important health consequences. Studies from several countries showed declines in acute care use at the beginning of the pandemic,[1–4] but these did not explore the impact among children with chronic conditions or differentiate hospital use for those with prevalent versus newly diagnosed disease, with the latter at potentially higher risk for delayed care. Two studies from the United Kingdom have analyzed mortality.[4,5] In Ontario, the first presumptive case of COVID-19 was announced on Jan. 25, 2020; on Mar. 15, a state of emergency was declared and on Mar. 19, health care providers were directed to halt or substantially reduce all elective or nonessential services.[6] We documented a significant decline in all pediatric primary care use during the early pandemic in Ontario,[7] and surveys reflected hesitancy in care-seeking due to fear of contracting SARS-CoV-2.[8] Hesitancy to seek care may result in more severe presentations of existing and new conditions.

We sought to estimate differences in rates of hospital use from baseline years, which would reflect potentially preventable morbidity from deferred care during the first 30 months after the pandemic onset, among children in Ontario, Canada.

Methods

Study design, setting and population

We conducted a population-based, repeated cross-sectional study of children (aged 0–17 yr) in Ontario, Canada. We compared monthly rates of outcomes in the first 30 pandemic months (Mar. 1, 2020, to Aug. 31, 2022) to those in the previous 3 years. We created annual cohorts of children who were residing in Ontario and eligible for provincial health care insurance on Jan. 1 of each year (2017–2022). For specific neonatal analyses, we created rolling cohorts of infants born in Ontario. We defined subpopulations of children with asthma, diabetes, inflammatory bowel disease and sickle cell anemia, chosen because they are chronic conditions that account for a high proportion of medical admissions, for which validated registries or case definitions exist and for which timely care can prevent the need for admission.[9] We also defined a group of children with neurologic impairment requiring technological assistance, chosen because they are medically fragile and have high health care needs that would be potentially affected by health system disruptions.[10] We defined all conditions and outcomes a priori. We followed the relevant reporting statements.[11,12]

Data sources

We used health and demographic databases housed and deterministically linked with encoded identifiers at ICES, a not-for-profit research institute whose legal status under Ontario's health information privacy law allows it to collect and analyze health data without consent (Appendix 1, eTable 1, available at www.cmaj.ca/lookup/doi/10.1503/cmaj.221726/tab-related-content).

We used demographic and vital statistics information from Ontario's health insurance registry. For baseline characteristics, we used postal codes for census-derived neighbourhood material deprivation quintiles.[13] We ascertained hospital admissions and emergency department outcomes using data from the Canadian Institute for Health Information. We used validated disease registries to capture data on children with asthma,[14] diabetes[15] and inflammatory bowel disease.[16] We further restricted the asthma group to those with active disease (an asthma health care encounter in the previous 2 years).[17] As in previous work, we used hospital record data since birth to define patients with sickle cell disease[18] and neurologic impairment with technology dependence (Appendix 1, eTable 2).[17,19]

Outcomes

We analyzed outcomes for the full population of children including all-cause, unplanned emergency department visits, medical and surgical hospital admissions, ICU admissions and all-cause mortality. We analyzed neonatal deaths (up to 28 days of life) separately. We defined acuity of emergency department visits using the Canadian Triage and Acuity Scale.[20] We further defined outcomes that could reflect deferred care, including new diagnoses, and more severe presentations, of diabetes and cancer (Appendix 1, eTable 2). We defined severe presentations for diabetes by the presence of diabetic ketoacidosis (DKA), shown to be associated with access to primary care,[21] and defined those for cancer by ICU admissions. Other clinical measures, such as cancer stage or longer-term mortality, were not available, and need for ICU is applicable to a range of cancer presentations from hematopoietic cancers to brain tumours. Other deferred care measures included admissions for acute ambulatory care–sensitive conditions (bacterial pneumonia, gastroenteritis, urinary tract infections and perforated appendicitis) using recommended definitions, which are widely used to measure access to timely care.[22] Among newborns, we analyzed 30-day readmissions for jaundice or hyperbilirubinemia and dehydration or feeding problems in a subset discharged within 7 days of birth.[23] For children with chronic conditions, we measured all-cause emergency department visits and hospital admissions, except for those with asthma and diabetes, for whom we analyzed disease-specific exacerbations only.

Exposure

The main exposure was the first 30 months of the COVID-19 pandemic.

Statistical analyses

We measured all outcomes from Jan. 1, 2017, to Aug. 31, 2022. We calculated weekly rates as the number of outcomes per 100 000 population by sex–age group. For incident cancer and diabetes, the denominators were total incident cases within the year and, for newborns, total births.

We used Poisson generalized estimating equations models with an autoregressive correlation structure (AR-1) for clustered count data to model pre-COVID-19 trends and used these to predict expected post-COVID-19 trends, as in previous work.[7] The unit of analysis was the week or month (depending on outcome) by sex–age group stratum. Pre-COVID-19 models included sex–age group indicators; a continuous linear term of time since Jan. 1, 2017, to estimate the general trend in each outcome through Feb. 29, 2020; and pre-COVID-19 month indicators to model monthly variations, with April as the reference. For new presentations of DKA, we did not include pre-COVID-19 month indicators as there was no seasonal variation.

We computed the expected rates of post-COVID-19 outcomes (and 95% confidence intervals [CIs]) from pre-COVID-19 regression coefficient estimates. The relative change in post-COVID-19 outcomes was expressed as the ratio of observed-to-expected rates.

We assessed pre-COVID-19 model fit by inspecting the plot of pre-COVID-19 observed and expected rates. When weekly rate models did not fit the data well or models did not converge because of rare events (i.e., all-cause deaths, urinary tract infections, new presentations of cancer and diabetes and associated severe presentations, perforated appendicitis and neonatal deaths), we used monthly rate models, and did not include the autoregressive correlation term. We conducted statistical analyses using SAS software, version 9.4 (SAS Institute Inc.).

Ethics approval

The use of data in this project was authorized under Section 45 of Ontario's *Personal Health Information Protection Act*, which does not require review by a research ethics board.

Table 1: Baseline characteristics of children in Ontario on Jan. 1 through the years 2017 to 2022

Characteristic	No. (%) of children					
	Prepandemic years			Pandemic years		
	2017 *n* = 2 898 449	2018 *n* = 2 911 762	2019 *n* = 2 933 999	2020 *n* = 2 958 684	2021 *n* = 2 967 282	2022 *n* = 2 924 363
Demographics						
Age group						
0–28 d	140 522 (4.8)	139 862 (4.8)	140 000 (4.8)	137 041 (4.6)	141 713 (4.8)	79 840 (2.7)
29–365 d	131 325 (4.5)	130 588 (4.5)	130 217 (4.4)	130 648 (4.4)	127 744 (4.3)	131 765 (4.5)
1–5 yr	741 875 (25.6)	743 536 (25.5)	744 871 (25.4)	751 065 (25.4)	746 052 (25.1)	740 280 (25.3)
6–12 yr	1 095 413 (37.8)	1 105 435 (38.0)	1 118 547 (38.1)	1 129 773 (38.2)	1 131 029 (38.1)	1 134 707 (38.8)
13–17 yr	789 314 (27.2)	792 341 (27.2)	800 364 (27.3)	810 157 (27.4)	820 744 (27.7)	837 771 (28.6)
Sex, female	1 410 927 (48.7)	1 417 252 (48.7)	1 428 878 (48.7)	1 440 426 (48.7)	1 444 642 (48.7)	1 423 655 (48.7)
Material deprivation						
Q1 (least deprived)	659 005 (22.7)	672 964 (23.1)	686 840 (23.4)	701 078 (23.7)	709 666 (23.9)	706 734 (24.2)
Q2	611 465 (21.1)	615 108 (21.1)	621 368 (21.2)	626 728 (21.2)	630 402 (21.2)	623 439 (21.3)
Q3	533 845 (18.4)	533 250 (18.3)	535 376 (18.2)	537 832 (18.2)	539 237 (18.2)	530 086 (18.1)
Q4	495 082 (17.1)	493 185 (16.9)	494 614 (16.9)	496 830 (16.8)	496 069 (16.7)	485 336 (16.6)
Q5 (most deprived)	564 662 (19.5)	561 853 (19.3)	559 156 (19.1)	557 715 (18.9)	551 912 (18.6)	536 704 (18.4)
Comorbidities						
Asthma	175 071 (6.0)	173 395 (6.0)	168 750 (5.8)	158 768 (5.4)	132 438 (4.5)	93 751 (3.2)
Diabetes	8606 (0.3)	8594 (0.3)	8732 (0.3)	8765 (0.3)	8884 (0.3)	9158 (0.3)
Sickle cell disease	834 (0.03)	843 (0.03)	855 (0.03)	866 (0.03)	854 (0.03)	851 (0.03)
Inflammatory bowel disease	2030 (0.1)	2031 (0.1)	2081 (0.1)	2126 (0.1)	2174 (0.1)	1967 (0.1)
Neurologic impairment with technology dependance	2415 (0.1)	2499 (0.1)	2560 (0.1)	2689 (0.1)	2720 (0.1)	2713 (0.1)

Table 2: Baseline characteristics of newborns in Ontario overall and those discharged within 7 days of birth

Characteristic	No. (%) of newborns*					
	Prepandemic years			Pandemic years		
	2017	2018	2019	2020	2021	2022
No. of all newborns	131 175	130 437	130 831	127 434	133 085	84 529
Birth weight, g, mean ± SD	3319.93 ± 572.78	3310.25 ± 574.10	3306.58 ± 566.36	3307.02 ± 565.33	3310.22 ± 568.69	3292.64 ± 566.82
Gestation, wk, mean ± SD	38.69 ± 1.97	38.64 ± 1.98	38.62 ± 1.93	38.60 ± 1.91	38.57 ± 1.92	38.54 ± 1.90
Vaginal birth	92 271 (70.3)	90 853 (69.7)	90 584 (69.2)	86 505 (67.9)	89 386 (67.2)	55 991 (66.2)
Cesarean birth	38 899 (29.7)	39 584 (30.3)	40 247 (30.8)	40 929 (32.1)	43 699 (32.8)	28 538 (33.8)
No. of newborns discharged within 7 days of birth†	125 795	125 132	125 364	122 197	127 773	81 372
Birth weight, g, mean ± SD	3363.77 ± 515.68	3353.72 ± 518.25	3350.59 ± 509.10	3349.35 ± 509.07	3352.75 ± 512.22	3333.73 ± 513.61
Gestation, wk, mean ± SD	38.88 ± 1.60	38.83 ± 1.61	38.81 ± 1.56	38.78 ± 1.55	38.76 ± 1.56	38.72 ± 1.55
Vaginal birth	89 590 (71.2)	88 284 (70.6)	87 987 (70.2)	84 045 (68.8)	87 038 (68.1)	54 659 (67.2)
Cesarean birth	36 202 (28.8)	36 848 (29.4)	37 377 (29.8)	38 152 (31.2)	40 735 (31.9)	26 713 (32.8)

Note: SD = standard deviation.
*Unless indicated otherwise.
†Includes a length of stay less than 7 days.

Results

Characteristics of the study population are shown in Table 1 (overall population) and Table 2 (newborns). In 2020, the proportion of children with select chronic conditions included 5.4% with active asthma, 0.3% with diabetes, 0.1% with inflammatory bowel disease, 0.03% with sickle cell disease and 0.1% with neurologic impairment with technological dependence.

Changes in hospital use and mortality

Immediately after Mar. 1, 2020, hospital use decreased dramatically, which recovered for emergency department visits by September 2021 and for medical admissions by May 2022, but which stayed below expected for ICU and surgical admissions throughout the observation period (Figure 1, Figure 2 and Figure 3). Compared with previous years, the overall adjusted relative rates (RRs) of emergency department visits and hospital admissions were 0.73 (95% CI 0.70–0.77) and 0.78 (95% CI 0.73–0.83), respectively (Appendix 1, eTable 3 and eTable 4). The reduction in emergency department visits was relatively consistent across acuity levels, with early recovery of low-acuity (Appendix 1, eTable 3) and medium-acuity visits (data not shown). Although observed mortality rates did not increase overall for either neonates or children, neonatal mortality had a sustained increase in the first 4 months of 2022 (peak adjusted RR 1.65, 95% CI 1.54–1.75) (Figure 4 and Appendix 1, eTable 5).

Newly diagnosed conditions

Overall, relative to expected, rates of new cancer or diabetes presentations did not increase, but there were notable differences by period. The first 3 months of the COVID-19 pandemic had significant decreases in rates of new cancer (range of adjusted RR 0.62–0.79) and subsequent increases for most of 2021 (peak adjusted RR 1.37, 95% CI 1.17–1.60 in June), as well as May through August 2022. Similarly, rates of newly diagnosed diabetes declined significantly in the first 3 months of the COVID-19 pandemic, (range of adjusted RR 0.52–0.85) but then increased for most of 2021 (peak adjusted RR 1.49, 95% CI 1.28–1.74 in July 2021) and much of 2022 (Figure 5, Figure 6 and Appendix 1, eTable 6). Whereas severe presentations of new cancers were not measurably different (adjusted RR 0.91, 95% CI 0.62–1.34), rates of DKA among new diabetes presentations were significantly higher in many pandemic months and overall (adjusted RR 1.14, 95% CI 1.00–1.30) (Figure 7, Figure 8 and Appendix 1, eTable 7).

Admissions for ambulatory care–sensitive conditions and newborn readmissions

Overall, admission rates for acute, infectious ambulatory care–sensitive conditions decreased significantly relative to expected, with an adjusted RR of 0.55 (95% CI 0.47–0.63) for gastroenteritis and of 0.41 (95% CI 0.34–0.49) for bacterial pneumonia with higher-than-expected rates of pneumonia from May to August 2022 (Figure 9 and Appendix 1, eTable 8) Admissions for urinary tract infections were also lower in the first 3 months of the pandemic, but not to the same degree as those for gastroenteritis and

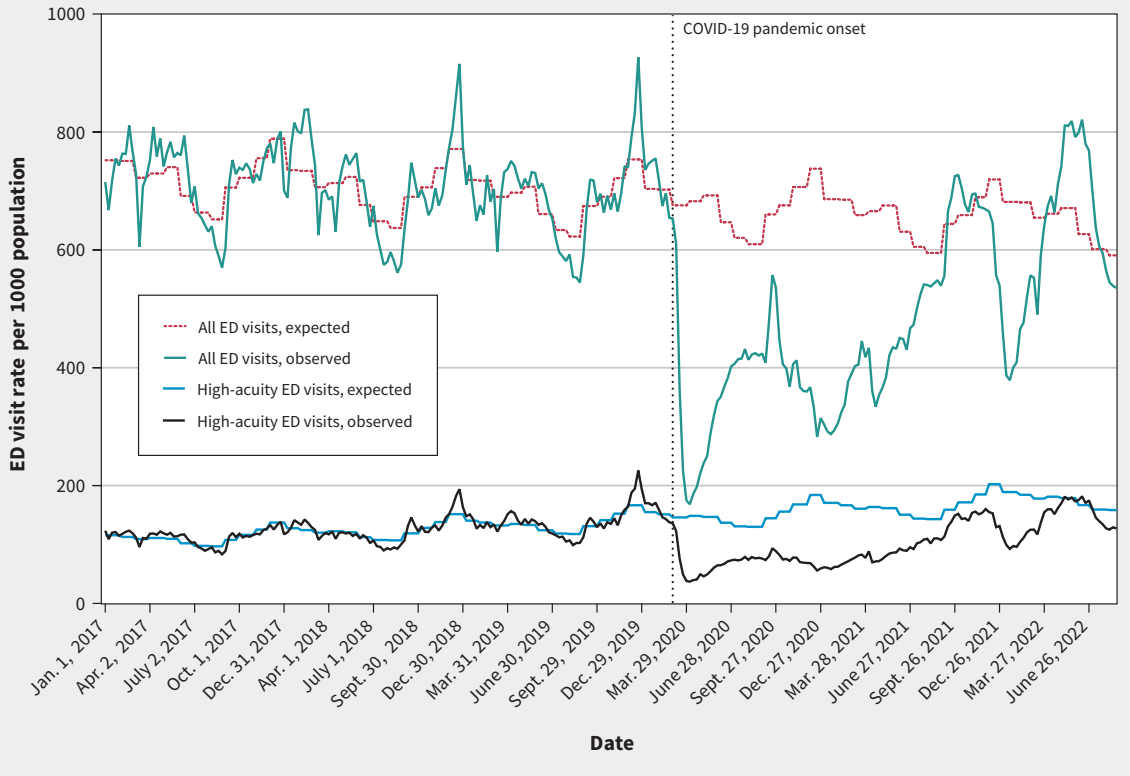

Figure 1: Expected and observed rates of all emergency department (ED) visits and high-acuity ED visits over time in Ontario.

pneumonia, and overall, were not different than predicted (adjusted RR 1.00, 95% CI 0.89–1.12) (Figure 10 and Appendix 1, eTable 8). Adjusted rates of perforated appendicitis were not significantly different than expected (adjusted RR 0.94, 95% CI 0.84–1.04) (Figure 10 and Appendix 1, eTable 9). Newborn readmissions decreased slightly overall, with an adjusted RR of 0.90 (95% CI 0.86–0.94) (Figure 11 and Appendix 1, eTable 9).

Admissions among children with pre-existing chronic conditions

Lower relative rates of hospital admissions were generally observed throughout the pandemic across almost all cohorts. Those with asthma and sickle cell disease had the lowest overall adjusted relative rates at 0.52 (95% CI 0.46–0.59) and 0.72 (95% CI 0.56–0.94), respectively, although there was a sustained period of higher rates of hospital admissions for asthma from June to August 2022 (peak adjusted RR 1.78, 95% CI 1.66–1.90 in June) (Figure 12 and Appendix 1, eTable 10). Admission rates were lower than expected for those with inflammatory bowel disease (through November 2020) and those with neurologic impairment with technology dependence (through June 2021), but were not significantly different overall for the observation period (Figure 12 and Appendix 1, eTable 11). Similar to those with asthma, admissions also saw a sustained increase among those with neurologic impairment in the spring and summer of 2022 (peak adjusted RR 1.39, 95% CI 1.24 to 1.56) (Appendix 1, eTable 11). The same overall trends were mirrored in emergency department visits (Figure 13 and Appendix 1, eTable 12 and eTable 13).

Interpretation

In this population-based study, we explored severe outcomes potentially related to deferred pediatric care in the 30 months after the declaration of a state of emergency in Ontario, Canada. We found relatively few measures of short-term harm for the indicators and populations studied. Our study has several strengths, including complete population and hospital coverage in a large Canadian province and validated outcomes sensitive to access to care in several cohorts of children with chronic conditions.

Overall, emergency department visits, including high-acuity visits, hospital admissions and ICU stays were lower and all-cause mortality did not increase. We found significant decreases in admissions for ambulatory care–sensitive conditions, newborn readmissions and hospital use among children with chronic conditions, especially early in the pandemic. We did, however, find evidence of potential delays in new diagnoses of cancer and diabetes, with lower relative rates early in the pandemic. In the case of diabetes, this was accompanied by higher-than-expected rates of DKA,

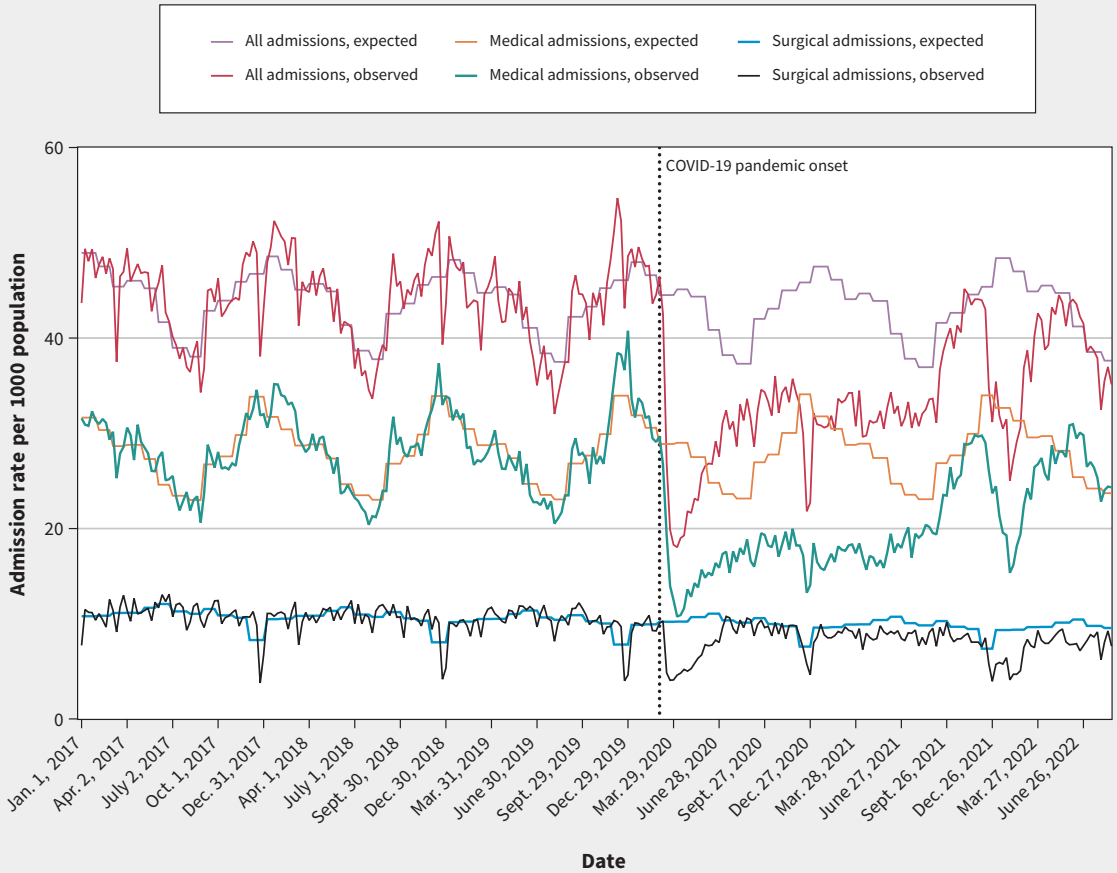

Figure 2: Expected and observed rates of all hospital admissions, medical admissions and surgical admissions over time in Ontario.

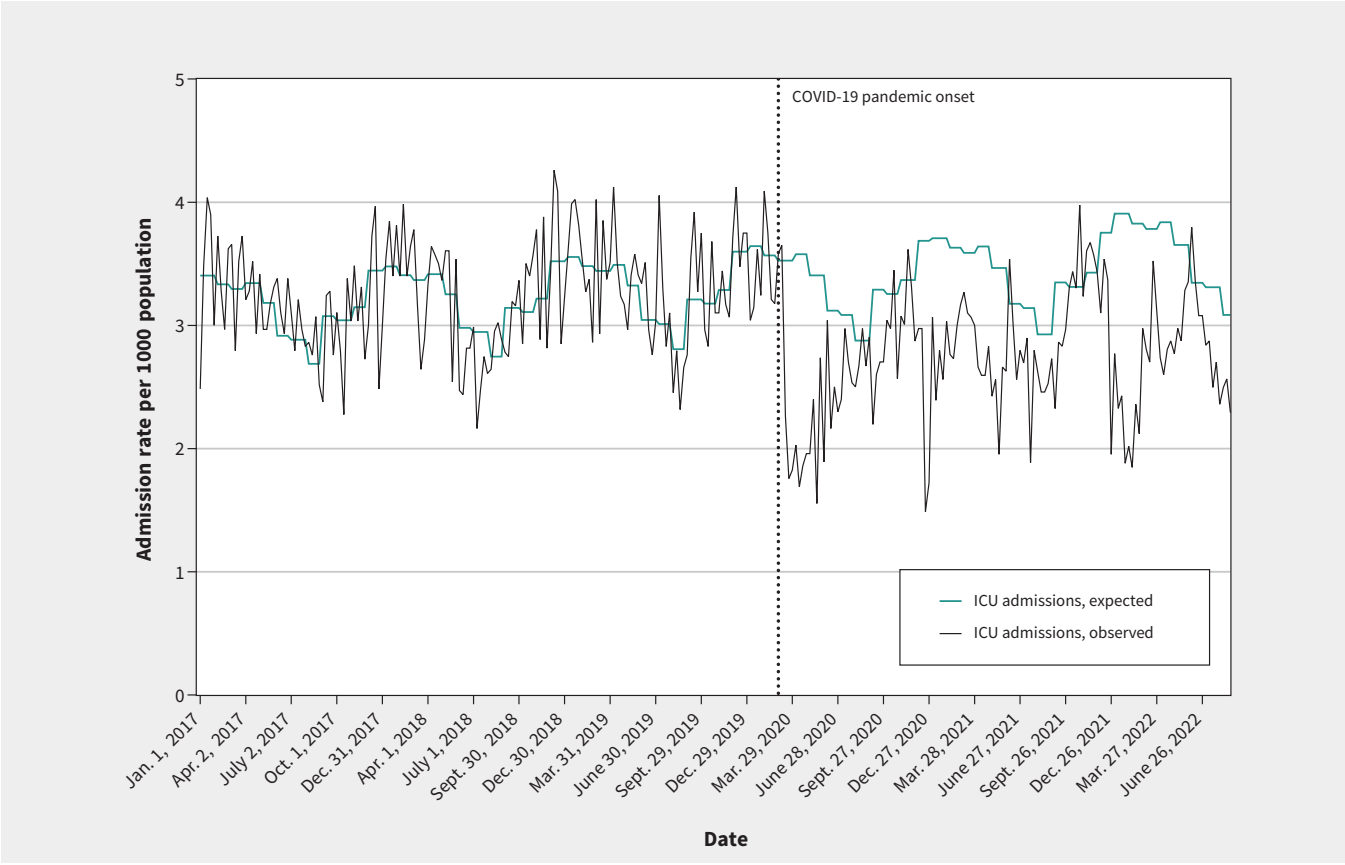

Figure 3: Expected and observed rates of intensive care unit (ICU) admissions over time in Ontario.

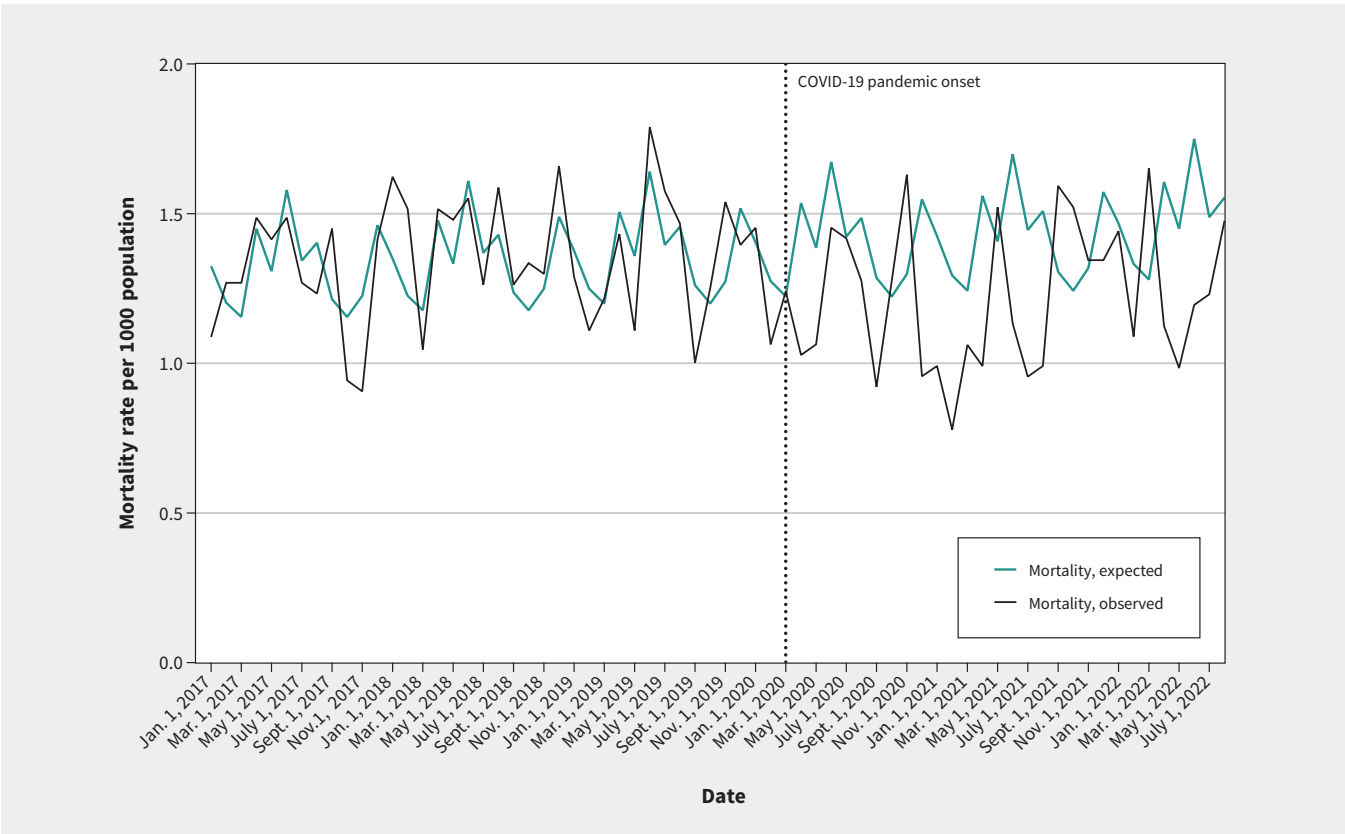

Figure 4: Expected and observed mortality over time in Ontario.

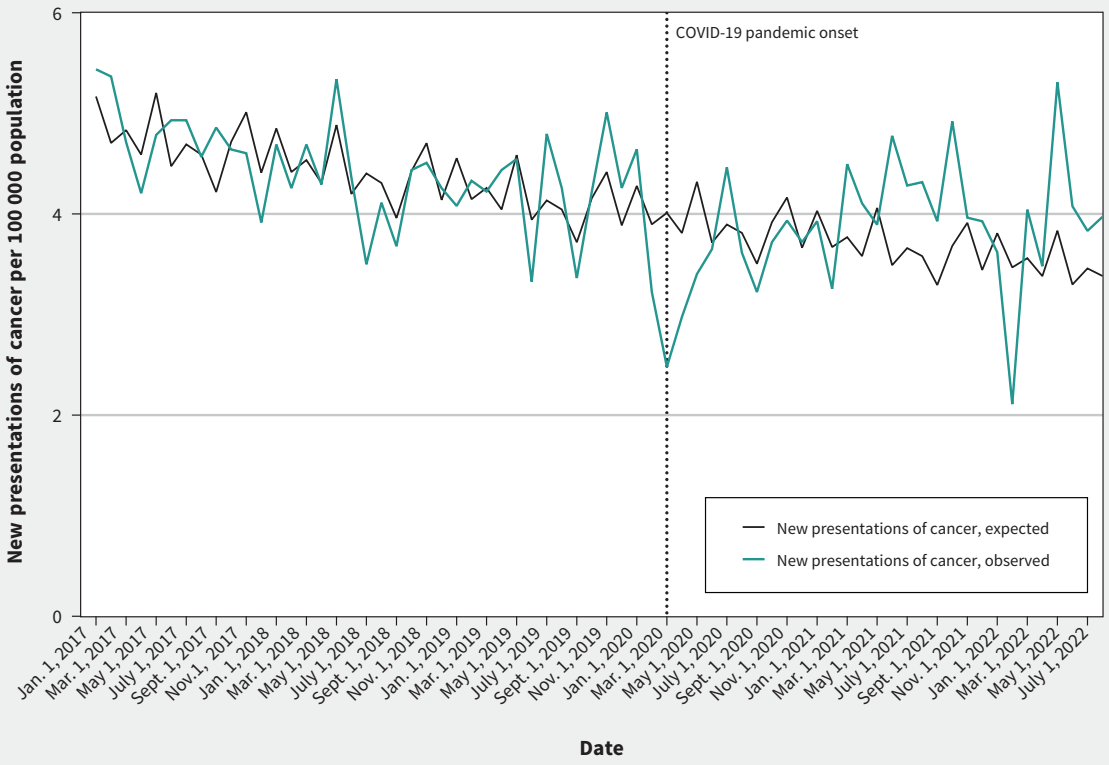

Figure 5: Expected and observed rates of new presentations of cancer over time in Ontario.

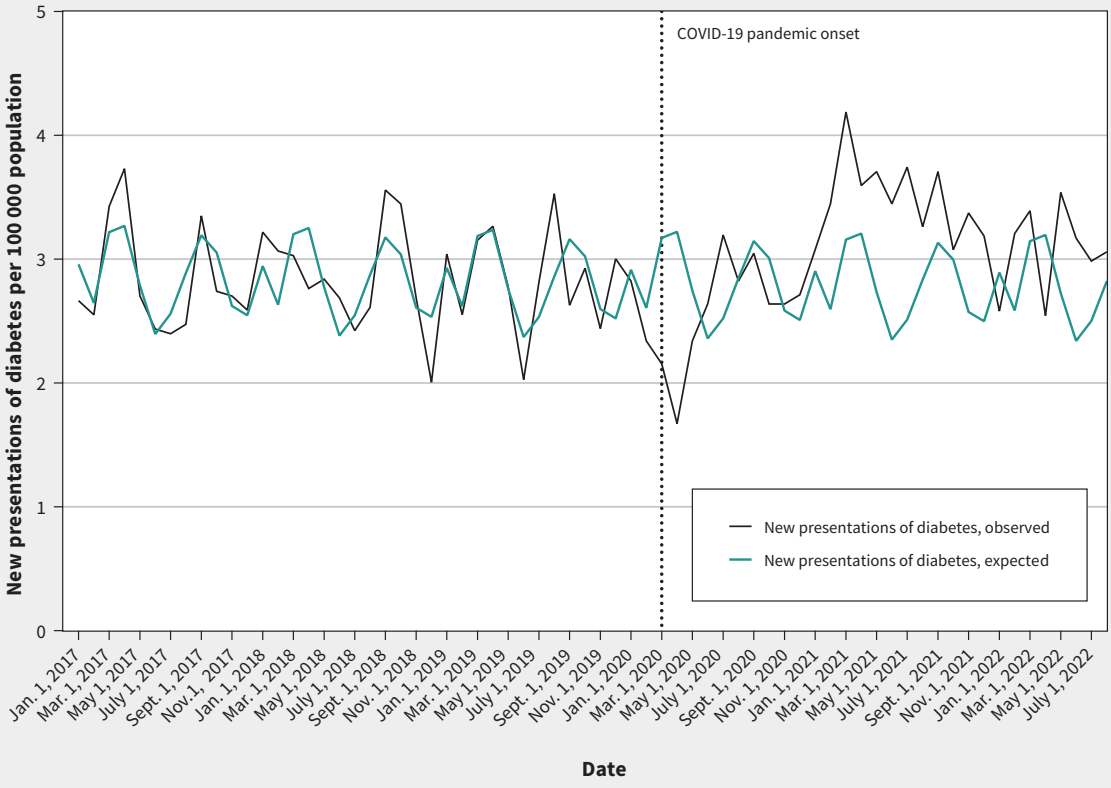

Figure 6: Expected and observed rates of new presentations of diabetes over time in Ontario.

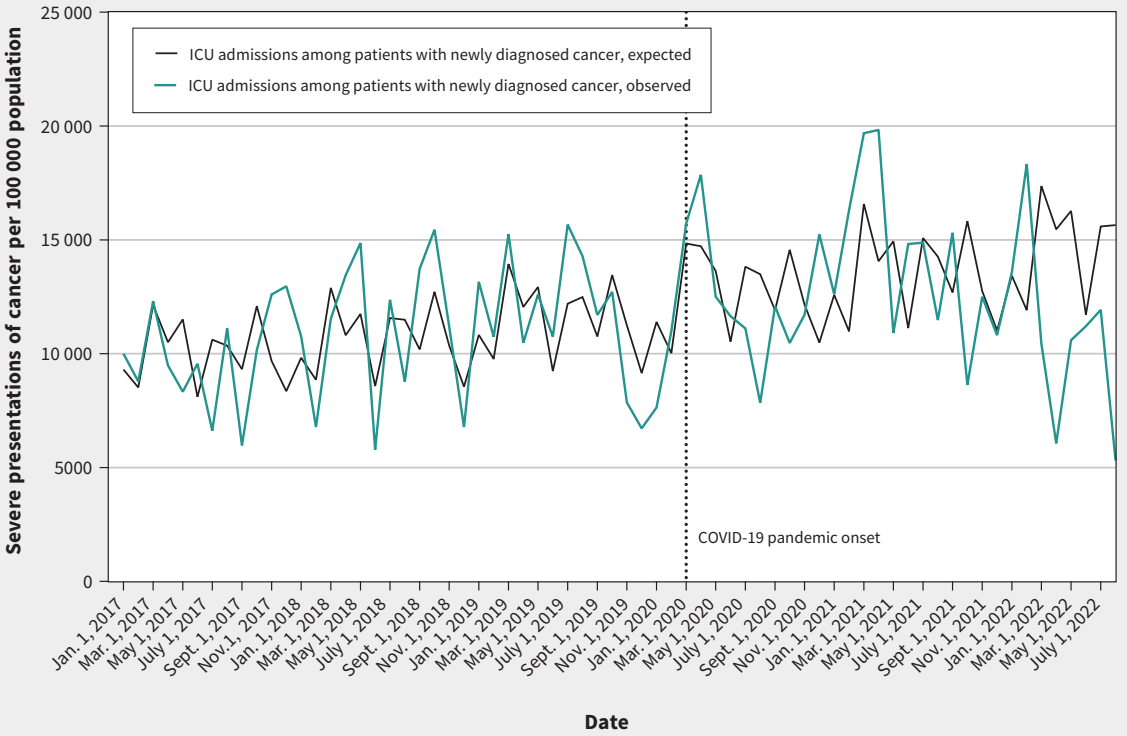

Figure 7: Expected and observed rates of severe presentations of cancer over time in Ontario. Note: ICU = intensive care unit.

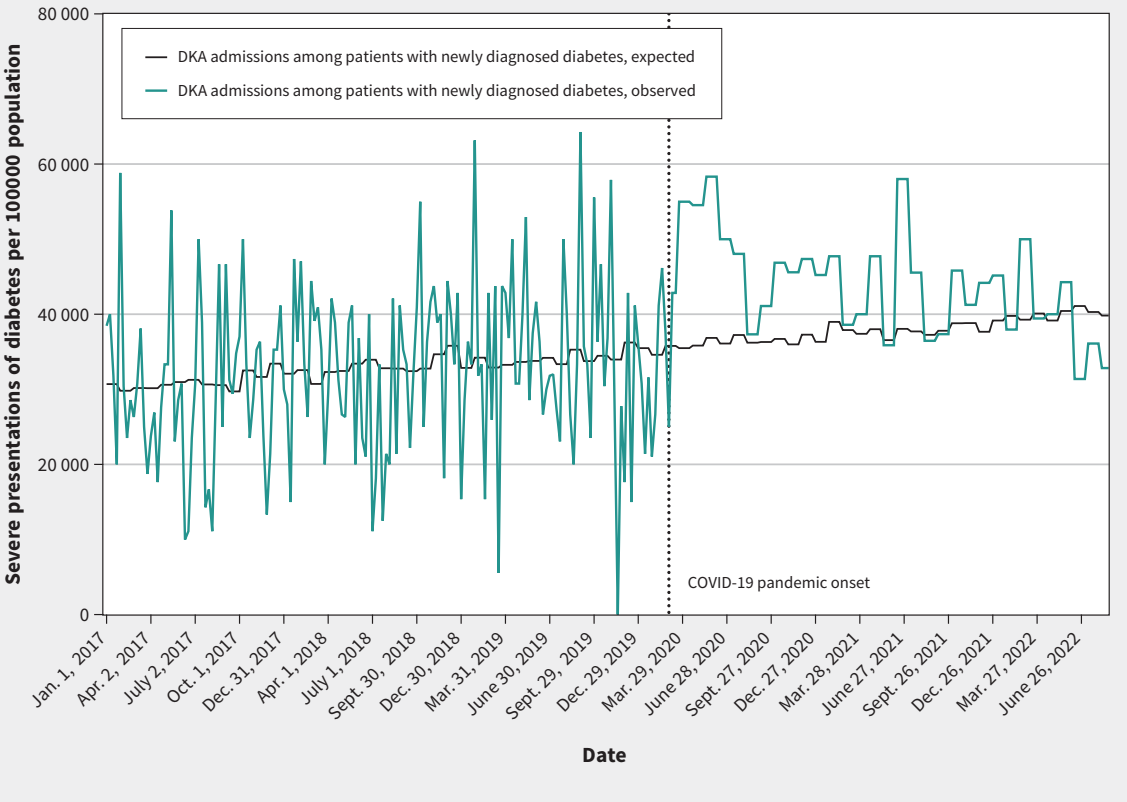

Figure 8: Expected and observed rates of severe presentations of diabetes over time in Ontario. Note: DKA = diabetic ketoacidosis.

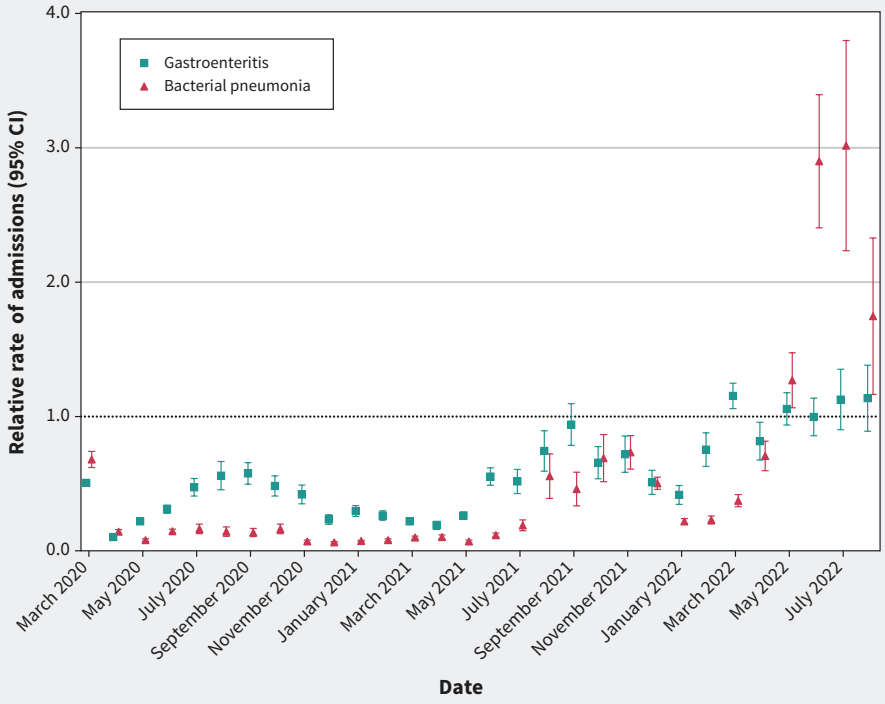

Figure 9: Relative monthly rates of gastroenteritis and bacterial pneumonia in Ontario after the onset of the COVID-19 pandemic, compared with pre-pandemic rates. Note: CI = confidence interval.

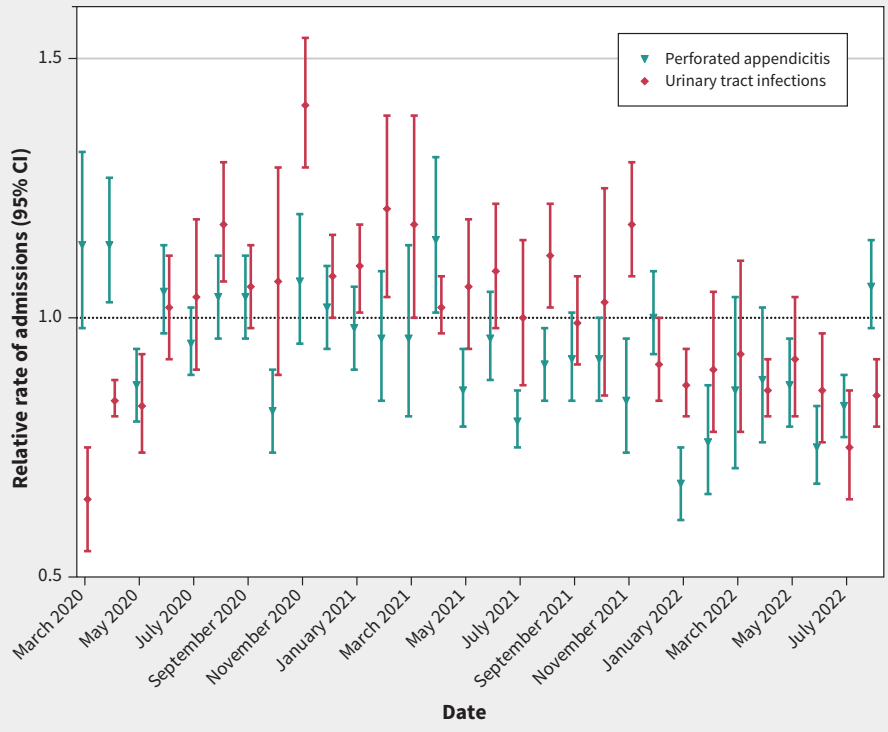

Figure 10: Relative monthly rates of perforated appendicitis and urinary tract infections in Ontario after the onset of the COVID-19 pandemic, compared with prepandemic rates. Note: CI = confidence interval.

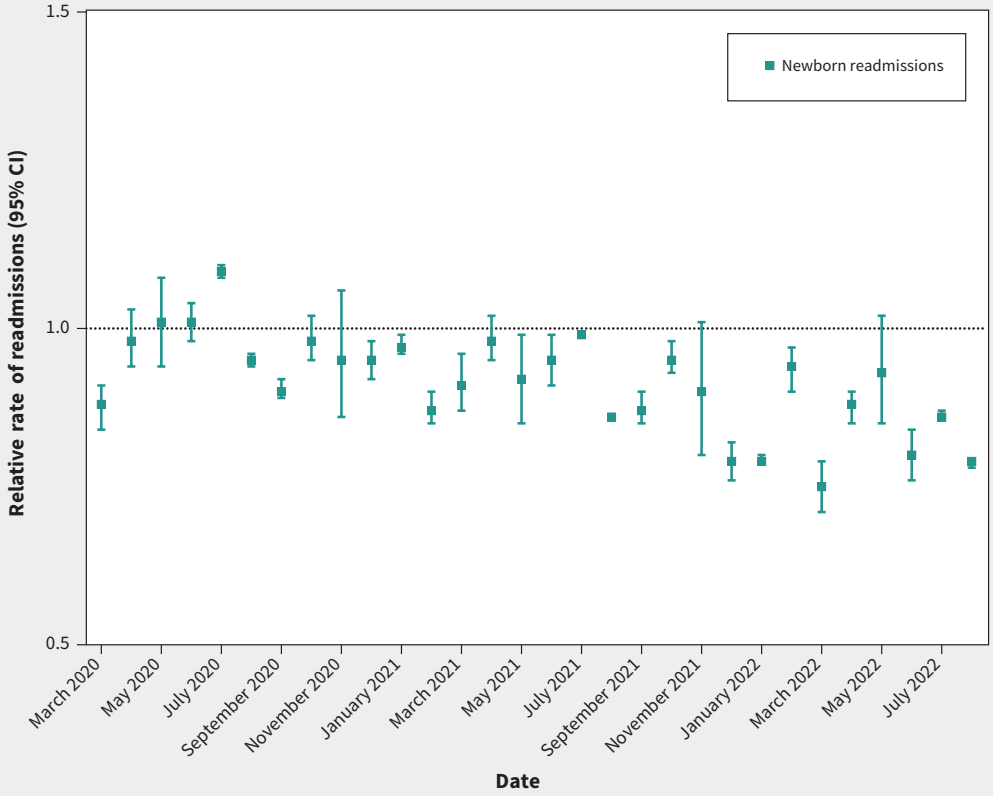

Figure 11: Relative monthly rates of newborn readmissions in Ontario after the onset of the COVID-19 pandemic, compared with prepandemic rates. Note: CI = confidence interval.

a preventable and potentially life-threatening complication, throughout the pandemic period. We also found higher-than-expected rates of new presentations of diabetes throughout 2021 and 2022. Our initial hypotheses had focused exclusively on the trends of new presentations to reflect changes in health care access and use, but emerging data worldwide have shown higher rates of pediatric type 1 diabetes mellitus associated with the pandemic,[24] although there is no consensus on cause. New cancer presentations showed a similar but less pronounced trend. Although a Canadian study using pediatric cancer registries found no change in the incidence of pediatric cancers, presentations with metastatic disease or early death in the first 9 months of the pandemic,[25] recent analyses from Germany's cancer registry document a pandemic-associated increase in many types of pediatric cancer presentations measured through March 2022.[26] Continued surveillance and research are necessary to investigate these trends in incidence in both diabetes mellitus and pediatric cancer.

Our finding of a relative decline in overall hospital use at the pandemic outset is consistent with other studies,[1,4,27,28] although most were limited to children's hospitals or pediatric emergency departments.[1,27,28] We extended these findings in this large population-based cohort study over a longer period of the pandemic through August 2022.

The overall decrease in hospital care was mirrored in the cohorts of children with chronic diseases. Other studies have documented lower admission rates for asthma, sickle cell crises and epilepsy in a sample of children's hospitals in the United States,[1,28] although these studies could not differentiate children with prevalent versus incident disease. Potential reasons for these trends include watchful waiting of sick children, fewer infections because of increased social distancing measures including school closures (reflected in the increase of infections we document in the latter part of the study period as restrictions eased) and preserved care with subspecialists.

Although no pediatric studies have analyzed a full list of ambulatory care–sensitive conditions, in contrast to our findings, a pediatric study from a single US centre reported higher rates of perforated appendicitis in the first 10 weeks of the pandemic.[29] Another study showed similar decreases in admissions for pneumonia, urinary tract infections and gastroenteritis during both the 2020 spring and summer pandemic periods.[1] We have shown previously that, during the pandemic, primary care visits for newborns in the first month of life increased,[7] which may have explained why preventable newborn readmissions were not elevated. This finding aligns with recently published literature from the US.[30] Our results of lower rates of gastroenteritis and pneumonia, but not of perforated appendicitis or urinary tract infections, likely reflects lower overall infection rates and transmission during most of the pandemic. In addition, many acute care visits for chronic disease exacerbations were likely for infections

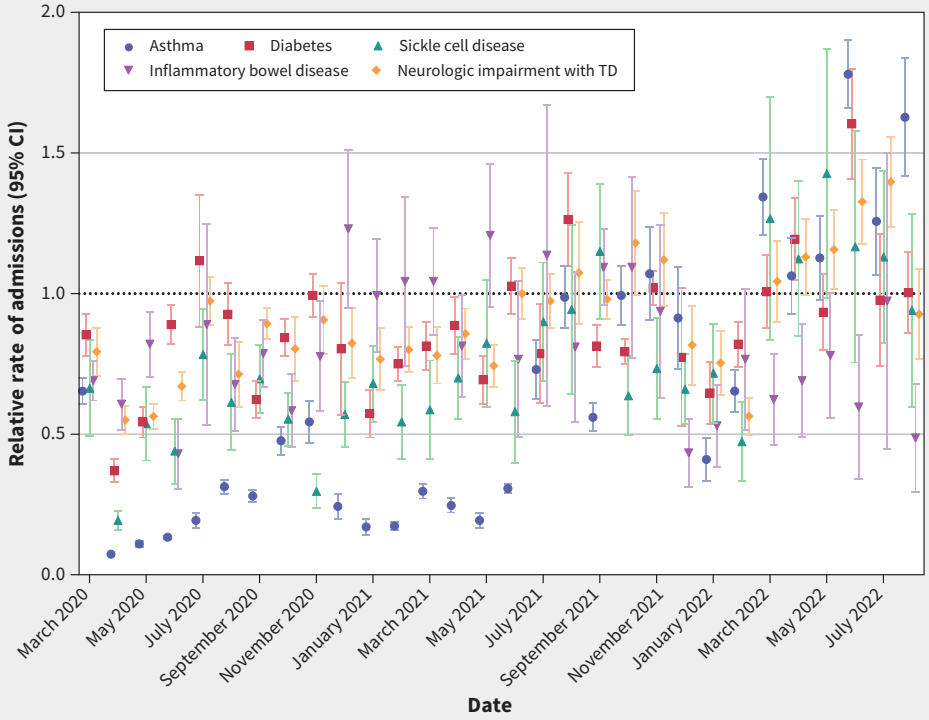

Figure 12: Relative monthly rates of admissions in Ontario after the onset of the COVID-19 pandemic by chronic disease type, compared with prepandemic rates. Note: CI = confidence interval, TD = technology dependence.

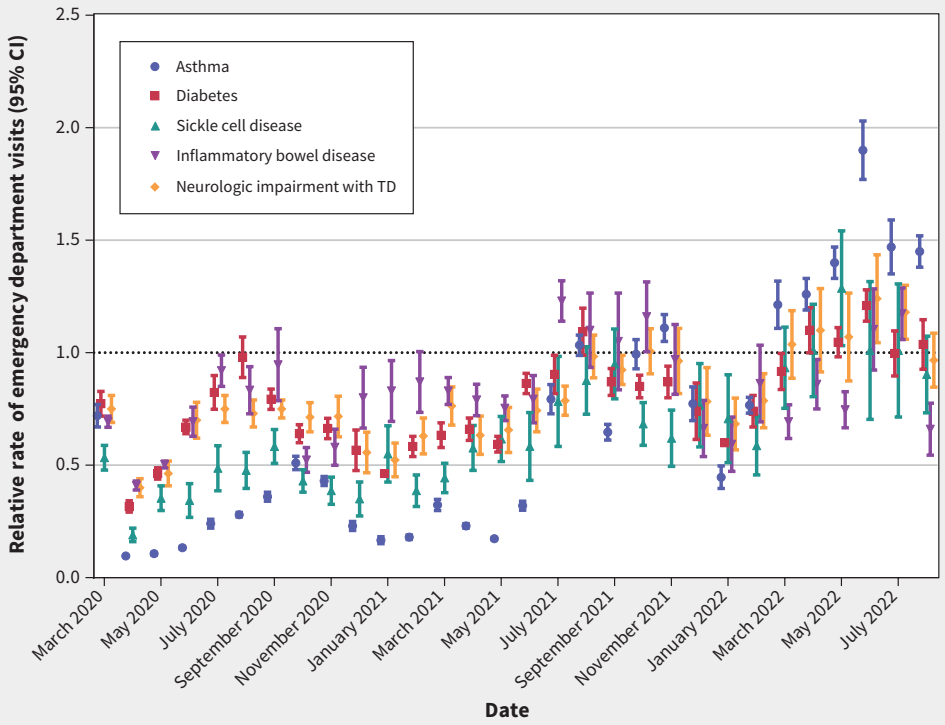

Figure 13: Relative monthly rates of emergency department visits in Ontario after the onset of the COVID-19 pandemic by chronic disease type, compared with prepandemic rates. Note: CI = confidence interval, TD = technology dependence.

(e.g., asthma and sickle cell exacerbations). Our findings of higher adjusted relative rates for hospital admission for pneumonia, and for admissions among those with asthma and neurologic impairment in the spring and summer of 2022, is likely due both to a longer season for influenza[31] and respiratory syncytial virus[32] and the lifting of other pandemic measures.

The higher relative risk of new presentations of diabetes with DKA is consistent with some, but not all, reports. Analyses from the early stages of the pandemic from Ontario (reporting a DKA proportion of 44.9% during the pandemic v. 33.1% before the pandemic), Canadian pediatric centres, a German registry and a UK survey all described higher rates of DKA among children with new type 1 diabetes.[33–36] By contrast, 2 American studies from pediatric hospitals found no difference in DKA during the initial pandemic months, but did not differentiate between new versus pre-existing disease.[1,28] We showed that admissions among children with existing disease were lower during the pandemic, which likely reflects, in part, continued access to specialty care. In addition, our study had a long follow-up period, which suggests that the risk for DKA on presentation persisted well past the first months of the pandemic. Another study by our team showed the increased rates of DKA in Ontario are likely related to delayed care-seeking, and not to other factors such as use of virtual primary care.[33]

We did not document an increase in all-cause mortality among children and neonates, although our findings included a sustained increase in neonatal mortality from January to April 2022. The childhood mortality findings are in keeping with both a Scottish retrospective cohort study that analyzed data from the early pandemic (March–August 2020)[4] and found no difference, and a recent analysis from England with data through Mar. 31, 2022, which showed 4% fewer deaths compared with the previous 3 years.[5] As cause-of-death data were not available, we could not discriminate between deaths that were potentially related to deferred care versus other aspects of the pandemic (e.g., injuries and infections). A systematic review on perinatal outcomes in the first year of the pandemic documented no increase in neonatal mortality in high-income countries.[37] Although our finding that the overall mortality rate did not increase is reassuring, and the increase we documented in 4 consecutive months in 2022 may be related to fluctuations of rare events, continued surveillance is warranted.

Limitations

Administrative data lack details that could describe clinically important measures of deferred care. For instance, although DKA on presentation with diabetes is a robust measure of access to care,[21] we were limited with respect to other conditions. We relied on diagnostic codes, and while hospital coding is known to be relatively accurate, some misclassification may be present, including for conditions such as perforated appendicitis;[38] however, we have no reason to believe misclassification changed over the study period. As we were unable to access timely data on cancer stage and deaths from registries, our measure for cancer severity was limited. Our findings cannot be generalized to clinical scenarios we did not study, including acute surgical conditions such as testicular torsion. We did not focus on the impact of the substantial delays in elective surgeries,[39] which may be associated with important negative clinical outcomes for children or other long-term consequences of pandemic-related health care restrictions.

Conclusion

Despite disruptions in access to primary care and changes in care-seeking behaviour, we documented relatively few changes in measures of severe preventable harm across selected outcomes and populations, except delays in diagnosing new cases of diabetes, with associated DKA on presentation. Mitigation strategies in future pandemics or other health system disruptions should include education campaigns around important signs and symptoms in children requiring medical attention.

References

1. Gill PJ, Mahant S, Hall M, et al. Reasons for admissions to US children's hospitals during the COVID-19 pandemic. *JAMA* 2021;325:1676-9.
2. Kadambari S, Goldacre R, Morris E, et al. Indirect effects of the COVID-19 pandemic on childhood infection in England: population based observational study. *BMJ* 2022;376:e067519.
3. Lazzerini M, Barbi E, Apicella A, et al. Delayed access or provision of care in Italy resulting from fear of COVID-19. *Lancet Child Adolesc Health* 2020;4:e10-1.
4. Williams TC, MacRae C, Swann OV, et al. Indirect effects of the COVID-19 pandemic on paediatric healthcare use and severe disease: a retrospective national cohort study. *Arch Dis Child* 2021;106:911-7.
5. Odd D, Stoianova S, Williams T, et al. Child mortality in England during the first 2 years of the COVID-19 pandemic. *JAMA Netw Open* 2023;6:e2249191.
6. COVID-19 intervention timeline in Canada. Ottawa: Canadian Institute for Health Information; updated 2021 Aug. Available: www.cihi.ca/en/covid-19-intervention-timeline-in-canada (accessed 2022 Nov. 30).
7. Saunders N, Guttmann A, Brownell M, et al. Pediatric primary care in Ontario and Manitoba after the onset of the COVID-19 pandemic: a population-based study. *CMAJ Open* 2021;9:E1149-E1158.
8. Anderson KE, McGinty EE, Presskreischer R, et al. Reports of forgone medical care among US adults during the initial phase of the COVID-19 pandemic. *JAMA Netw Open* 2021;4:e2034882.
9. Gill PJ, Thavam T, Anwar MR, et al. Prevalence, cost, and variation in cost of pediatric hospitalizations in Ontario, Canada. *JAMA Netw Open* 2022;5:e2147447.
10. Cohen E, Berry JG, Camacho X, et al. Patterns and costs of health care use of children with medical complexity. *Pediatrics* 2012;130:e1463-70.
11. 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.
12. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies. *Int J Surg* 2014;12:1495-9.
13. Matheson FI, Dunn JR, Smith KL, et al. Development of the Canadian Marginalization Index: a new tool for the study of inequality. *Can J Public Health* 2012;103(Suppl 2):S12-6.
14. To T, Dell S, Dick PT, et al. Case verification of children with asthma in Ontario. *Pediatr Allergy Immunol* 2006;17:69-76.
15. Guttmann A, Nakhla M, Henderson M, et al. Validation of a health administrative data algorithm for assessing the epidemiology of diabetes in Canadian children. *Pediatr Diabetes* 2010;11:122-8.
16. Benchimol EI, Guttmann A, Griffiths AM, et al. Increasing incidence of paediatric inflammatory bowel disease in Ontario, Canada: evidence from health administrative data. *Gut* 2009;58:1490-7.
17. Gershon AS, Wang C, Guan J, et al. Identifying patients with physician-diagnosed asthma in health administrative databases. *Can Respir J* 2009;16:183-8.
18. Cohen E, Gandhi S, Toulany A, et al. Health care use during transfer to adult care among youth with chronic conditions. *Pediatrics* 2016;137:e20152734.

19. Children and youth with medical complexity in Canada. Ottawa: Canadian Institute for Health Information; 2020.
20. Jiménez JG, Murray MJ, Beveridge R, et al. Implementation of the Canadian Emergency Department Triage and Acuity Scale (CTAS) in the Principality of Andorra: Can triage parameters serve as emergency department quality indicators? *CJEM* 2003;5:315-22.
21. Nakhla M, Rahme E, Simard M, et al. Risk of ketoacidosis in children at the time of diabetes mellitus diagnosis by primary caregiver status: a population-based retrospective cohort study. *CMAJ* 2018;190:E416-21.
22. Pediatric Quality Indicators overview. Rockville (MD): Agency for Healthcare Research and Quality. Available: https://www.qualityindicators.ahrq.gov/Modules/pdi_resources.aspx#techspecs (accessed 2021 Sept. 10).
23. Jones E, Taylor B, Rudge G, et al. Hospitalisation after birth of infants: cross sectional analysis of potentially avoidable admissions across England using hospital episode statistics. *BMC Pediatr* 2018;18:390. doi: 10.1186/s12887-018-1360-z.
24. D'Souza D, Empringham J, Pechlivanoglou P, et al. Incidence of diabetes in children and adolescents during the COVID-19 pandemic: a systematic review and meta-analysis. *JAMA Netw Open* 2023;6:e2321281.
25. Pelland-Marcotte MC, Xie L, Barber R, et al. Incidence of childhood cancer in Canada during the COVID-19 pandemic. *CMAJ* 2021;193:E1798-E1806.
26. Erdmann F, Spix C, Schrappe M, et al. Temporal changes of the incidence of childhood cancer in Germany during the COVID-19 pandemic: updated analyses from the German Childhood Cancer Registry. *Lancet Reg Health Eur* 2022;17:100398.
27. Finkelstein Y, Maguire B, Zemek R, et al. Effect of the COVID-19 pandemic on patient volumes, acuity, and outcomes in pediatric emergency departments: a nationwide study. *Pediatr Emerg Care* 2021;37:427-34.
28. Pelletier JH, Rakkar J, Au AK, et al. Trends in US pediatric hospital admissions in 2020 compared with the decade before the COVID-19 pandemic. *JAMA Netw Open* 2021;4:e2037227.
29. Place R, Lee J, Howell J. Rate of pediatric appendiceal perforation at a children's hospital during the COVID-19 pandemic compared with the previous year. *JAMA Netw Open* 2020;3:e2027948.
30. Handley SC, Gallagher K, Breden A, et al. Birth hospital length of stay and rehospitalization during COVID-19. *Pediatrics* 2022;149:e2021053498.
31. Ben Moussa M, Buckrell S, Rahal A, et al. National influenza mid-season report, 2022-2023: a rapid and early epidemic onset. *Can Commun Dis Rep* 2023;49:10-4.
32. Viñeta Paramo M, Ngo LPL, Abu-Raya B, et al. Respiratory syncytial virus epidemiology and clinical severity before and during the COVID-19 pandemic in British Columbia, Canada: a retrospective observational study. *Lancet Reg Health Am* 2023;25:100582.
33. Shulman R, Nakhla M, Diong C, et al. Health care use prior to diabetes diagnosis in children before and during COVID. *Pediatrics* 2022;150:e2022058349. doi: 10.1542/peds.2022-058349.
34. Ho J, Rosolowsky E, Pacaud D, et al. Diabetic ketoacidosis at type 1 diabetes diagnosis in children during the COVID-19 pandemic. *Pediatr Diabetes* 2021;22:552-7.
35. Ng SM, Woodger K, Regan F, et al. Presentation of newly diagnosed type 1 diabetes in children and young people during COVID-19: a national UK survey. *BMJ Paediatr Open* 2020;4:e000884.
36. Kamrath C, Monkemoller K, Biester T, et al. Ketoacidosis in children and adolescents with newly diagnosed type 1 diabetes during the COVID-19 pandemic in Germany. *JAMA* 2020;324:801-4.
37. Chmielewska B, Barratt I, Townsend R, et al. Effects of the COVID-19 pandemic on maternal and perinatal outcomes: a systematic review and meta-analysis. *Lancet Glob Health* 2021;9:e759-72.
38. CIHI Data Quality Study of the 2006–2007 Discharge Abstract Database. Ottawa: Ontario Canadian Institute for Health Information; 2009.
39. Casey L. Ontario pediatrics hospitals ask for help to deal with backlog of 12 000 surgeries. *CBC News* 2023 Jan. 22. Available: https://www.cbc.ca/news/canada/toronto/ontario-children-surgery-waitlists-1.6722402.

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Data sharing: The data set from this study is held securely in coded form at ICES. While legal data sharing agreements between ICES and data providers prohibit ICES from making the dataset publicly available, access may be granted to those who meet pre-specified criteria for confidential access, available at www.ices.on.ca/DAS (email: das@ices.on.ca). The full dataset creation plan and underlying analytic code are available from the authors upon request, understanding that the computer programs may rely upon coding templates or macros that are unique to ICES and are therefore either inaccessible or may require modification.

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