

Effect of the COVID-19 Pandemic on Patient Volumes, Acuity, and Outcomes in Pediatric Emergency Departments

A Nationwide Study

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Objectives: The aim of this study was to quantify the effect of the COVID-19 pandemic on pediatric emergency department (ED) utilization and outcomes.

Methods: This study is an interrupted-time-series observational study of children presenting to 11 Canadian tertiary-care pediatric EDs. Data were grouped into weeks in 3 study periods: prepandemic (January 1, 2018–January 27, 2020), peripandemic (January 28, 2020–March 10, 2020), and early pandemic (March 11, 2020–April 30, 2020). These periods were compared with the same time intervals in the 2 preceding calendar years. Primary outcomes were number of ED visits per week. The secondary outcomes were triage acuity, hospitalization, intensive care unit (ICU) admission, mortality, length of hospital stay, ED revisits, and visits for trauma and mental health concerns.

Results: There were 577,807 ED visits (median age, 4.5 years; 52.9% male). Relative to the prepandemic period, there was a reduction [−58%; 95% confidence interval (CI), −63% to −51%] in the number of ED visits during the early-pandemic period, with concomitant higher acuity. There was a concurrent increase in the proportion of ward [odds ratio (OR), 1.39; 95% CI, 1.32–1.45] and intensive care unit (OR, 1.20; 95% CI,

1.01–1.42) admissions, and trauma-related ED visits among children less than 10 years (OR, 1.51; 95% CI, 1.45–1.56). Mental health–related visits in children declined in the early-pandemic period (in <10 years, −60%; 95% CI, −67% to −51%; in children ≥10 years: −56%; 95% CI, −63% to −47%) relative to the pre-COVID-19 period. There were no differences in mortality or length of stay; however, ED revisits within 72 hours were reduced during the early-pandemic period (percent change: −55%; 95% CI, −61% to −49%; $P < 0.001$).

Conclusions: After the declaration of the COVID-19 pandemic, dramatic reductions in pediatric ED visits occurred across Canada. Children seeking ED care were sicker, and there was an increase in trauma-related visits among children more than 10 years of age, whereas mental health visits declined during the early-pandemic period. When faced with a future pandemic, public health officials must consider the impact of the illness and the measures implemented on children's health and acute care needs.

Key Words: COVID-19, pandemics, triage, public health, hospitalization, emergency services, hospital

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As the COVID-19 pandemic began to claim lives around the globe, various public health measures were implemented to control the spread of SARS-CoV-2.¹ Many countries instituted stay-at-home orders, curfews, and lockdowns in an attempt to contain the virus spread.² These interventions may have contributed to the perception that the hospital environment represents a reservoir of infection, which translated to an associated reduction in emergency department (ED) visits.³ National syndromic surveillance data in the United States reported that ED visits declined by 42% between April 2019 and April 2020.⁴ During this period, visits for myocardial infarction, stroke, and hyperglycemic crisis (adult health conditions that necessitate immediate care) declined by 23%, 20%, and 10%, respectively.⁵

Smaller reports from pediatric EDs have suggested similar trends.^{6–8} The subsequent altered care-seeking patterns may lead to unnecessary morbidity by delaying access to care for urgent conditions.⁹ Although previous reports have identified reductions in pediatric EDs visits, these have generally been restricted to single institutions,⁶ specific diagnoses,¹⁰ or populations¹¹ or regions within countries¹² and lacked details regarding disease acuity and outcomes.

Adult studies in France¹³ and Italy¹⁴ examining the effect of the COVID-19 pandemic reported increases in out-of-hospital cardiac arrests and reductions in out-of-hospital cardiac arrest survival rates, markers of health care system handling of emergencies. Although these findings might be partly related to direct COVID-19 deaths, indirect effects through lockdown, behavior changes, and pandemic-related health system issues (overwhelming of emergency medical services and postponement of consultations and scheduled nonurgent procedures) likely are significant

contributors. Patients may have more difficulty obtaining medical evaluations due to lockdown and movement restrictions, and they may also be reluctant to present to EDs because of fear of exposure to COVID-19 or long waiting times. Although no similar data are available for children, a survey conducted by the British Pediatric Surveillance Unit in April 2020 identified 9 pediatric deaths over a 14-day period, possibly associated with delayed presentations because of the pandemic.¹⁵

We conducted a nationwide study of Canada's tertiary-care pediatric centers to quantify the effect of the pandemic on pediatric ED utilization and disease severity. Using a national network, we sought to determine the effect of key pandemic-related events on the number of children treated in the country's tertiary-care pediatric centers, the acuity of illness at presentation, and patient outcomes.

METHODS

Design and Setting

We conducted an interrupted-time-series study to compare pediatric ED visit numbers, disease severity, disposition, and outcomes during the early phase of the pandemic with similar non-COVID-19 periods during 2018 and 2019. The 15 Canadian pediatric tertiary care centers, all members of the Pediatric Emergency Research Canada network,¹⁶ were invited to participate; 11 centers provided aggregate data with a waiver of patient consent after approval by their respective research ethics board.

The 2 years preceding the pandemic (2018 and 2019) were selected to represent the periods without major events influencing ED volumes or acuity of presentations. We studied identical calendar periods (January 1–April 30 of each year) to minimize seasonal differences in ED volumes and chief complaints, which enabled us to focus on 2 a priori selected important COVID-19–related events. The first was the confirmation of the first COVID-19 case in Canada (January 27, 2020),¹⁷ and the second was the declaration of a global pandemic by the World Health Organization (WHO) (March 11, 2020).¹⁸ Thus, we defined 3 separate study periods: period 1 (prepandemic: January 1, 2018–January 28, 2020), period 2 (peripandemic: January 29, 2020–March 10, 2020), and period 3 (early pandemic: March 11, 2020–April 30, 2020).

Participants and Data Sources

Site investigators engaged local data analysts (blinded to study hypotheses and outcomes), who identified eligible children and extracted patient data using electronic medical records, and provided aggregate site-level data. Participants included all children 18 years or younger who presented to a participating ED. Re-presentation within 72 hours of the index visit was classified as revisits related to the index visit rather than independent ED visits. All patient visits and associated variables were grouped weekly.

Outcomes

The primary outcome was the number of pediatric ED visits per week. We examined 8 secondary outcomes: 1) presentation acuity, defined by the Pediatric Canadian Triage and Acuity Scale (PaedCTAS), 2) hospitalization, 3) intensive care unit (ICU) admission, 4) death, 5) length of hospital stay of admitted patients, 6) repeat ED visits within 72 hours of ED discharge, 7) trauma-related ED visits, and 8) mental health-related ED visits. The latter 2 were explored as there have been disparate reports regarding the impact of the COVID-19 pandemic on their occurrence.^{19–21} Emergency department visit–related discharge diagnoses were classified using the assigned visit *International Classification of Disease Version 10 (ICD-10)* code. Trauma presentations were identified by *ICD-10*

codes S00–S99, T07, T14–T28, and T30–T34; mental health–related ED visits were defined by codes F04–F99, T14.91, and R45.851.

Statistical Analysis

We used an interrupted-time-series design to enable a longitudinal comparison of outcomes between the exposure (peripandemic/early-pandemic COVID-19) and control periods to evaluate the impact of the selected events on the outcomes of interest.

The primary outcome, the aggregated total number of ED visits per week, was assessed using interrupted-time-series quasi-Poisson regression models, which accounted for seasonal and secular trends using year and calendar week number terms, respectively.^{22,23} Correlograms of the autocorrelation and partial autocorrelation along with plots of the model residuals were used to assess model fit.²³

The outcome of acuity was classified using the PaedCTAS score, a nationally adopted tool used by triage nurses to classify the acuity of ED presentation, prioritize access, and anticipate the intensity of care required.²⁴ This 5-level ordinal score ranges from I (resuscitation) to V (nonurgent).²⁵ The PaedCTAS score, which is strongly associated with ICU admission, probability of leaving without being seen, and length of stay,²⁶ is assigned by experienced and trained ED nurses.²⁴

For the outcomes of acuity, hospitalization, ICU admission, and 72-hour ED revisits, we investigated the overall number of events and their relative proportion of all ED visits. Quasi-Poisson regression models were used to measure weekly changes, and binomial regression models measured changes in the proportion and odds ratios (ORs) of these events relative to the total number of ED visits between the 3 study periods. The proportion of ED visits that resulted in death at each study site was compared between the 3 study years using a mixed effects logistic regression model that included a fixed effect for calendar year and a random effect to account for the repeated measurement of each site.

The outcomes of trauma- and mental health–related ED visits were analyzed stratified by age (<10 years vs ≥10 years). The length of hospitalization (monthly mean) was modeled using a linear mixed effects regression model with month and year terms as fixed effects, and a random intercept per site.

All *P* values reported represent 2-sided tests of significance, and results were deemed statistically significant at *P* < 0.05. All analyses were completed using R 3.6.0 (R Project for Statistical Computing).

RESULTS

We included 577,807 ED visits, of which 211,085 (36.5%), 207,673 (35.9%), and 159,049 (27.5%) occurred in 2018, 2019, and 2020, respectively. Participant median age was 4.5 years (interquartile range, 1.5–10.5 years); 52.9% of ED visits were by males.

Primary Outcome

The range in the mean weekly number of ED presentations at each site varied between study periods—prepandemic, 757 ± 67 to 1652 ± 179; peripandemic, 746 ± 42 to 1504 ± 39; early pandemic, 294 ± 116 to 740 ± 220 (Table 1, eFig. 1, Supplemental Digital Content, <http://links.lww.com/PEC/A776>). During the peripandemic period, there were no differences from expected estimates in the number of ED visits, compared with the prepandemic period [percent change from pre-COVID, −3%; 95% confidence interval (CI), −12% to +7%; *P* = 0.52]. In contrast, there was a significant decrease in the number of ED visits during the early-pandemic period, compared with the expected estimates (percent change, −58%; 95% CI, −63% to −51%; *P* < 0.001; Figure 1).

TABLE 1. Mean (and SD) Number of Weekly ED Visits by Site During the Prepandemic, Peripandemic, and Early-Pandemic Periods

Site	Prepandemic Period	Peripandemic Period	Early-Pandemic Period
The Hospital for Sick Children, Toronto, ON	1652 (179)	1470 (86)	740 (220)
The Children’s Hospital of Eastern Ontario, Ottawa, ON	1563 (140)	1239 (293)	424 (164)
The Alberta Children’s Hospital, Calgary, AB	1481 (70)	1504 (39)	727 (210)
Montreal Children’s Hospital, Montreal, QC	1580 (130)	1427 (209)	505 (238)
McMaster Children’s Hospital, Hamilton, ON	1073 (110)	1062 (77)	430 (174)
Stollery Children’s Hospital, Edmonton, AB	1088 (65)	1053 (51)	468 (162)
British Columbia Children’s Hospital, Vancouver, BC	1046 (101)	1062 (62)	470 (187)
The Children’s Hospital of Winnipeg, Winnipeg, MB	1006 (80)	932 (21)	442 (175)
Children’s Hospital, London Health Sciences Centre, London, ON	761 (65)	746 (42)	294 (116)
IWK Health Centre, Halifax, NS	757 (67)	926 (75)	318 (156)
Jim Pattison Children’s Hospital, Saskatoon, SK	387 (70.4)	557 (45)	182 (76.9)

Secondary Outcomes

Acuity

The acuity of ED visits increased as reflected by an increased proportion of PaedCTAS level II visits in the early-pandemic period (OR, 1.03; 95% CI, 1.00–1.07; *P* = 0.04) and reduction in PaedCTAS level V visits in the peripandemic (OR, 0.96; 95% CI, 0.93–0.99; *P* = 0.01) and early-pandemic periods (OR, 0.93; 95% CI, 0.89–0.97; *P* = 0.002), compared with the prepandemic period (Fig. 2).

Hospitalizations (Non-ICU)

The number and proportion of hospitalizations did not change in the peripandemic period compared with the prepandemic period. Although the number of hospitalizations decreased during the

early-pandemic period (percent change from prepandemic, –41%; 95% CI, –45% to –37%; *P* < 0.001), we observed an increase in the proportion of children who were hospitalized (OR, 1.39; 95% CI, 1.32–1.45; *P* < 0.001; Table 2).

Intensive Care Unit Admissions

Although the number of ICU admissions was reduced during the early-pandemic compared with prepandemic period (percent change, –49%; 95% CI, –59% to –37%; *P* < 0.001), the proportion of ED visits resulting in ICU admissions increased (OR, 1.20; 95% CI, 1.01–1.42; Table 2).

Length of Hospital Stay—All Admissions

The mean length of hospitalization was 5.03 ± 1.07, 5.00 ± 1.09, and 4.72 ± 0.93 days in 2018, 2019, and 2020, respectively;

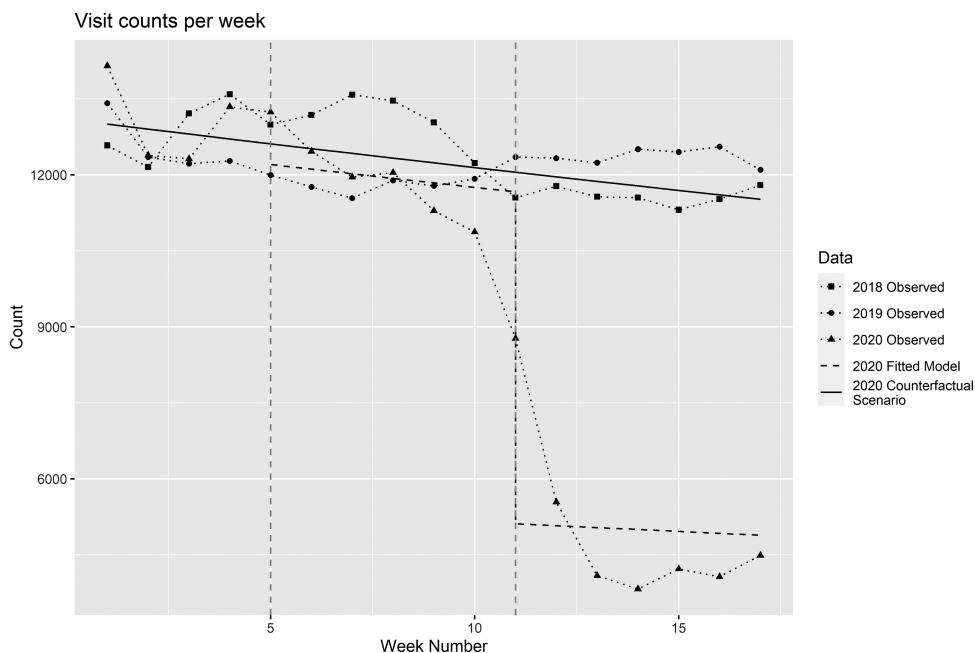


FIGURE 1. Number of ED visits per week combined for all 11 participating hospitals (dashed lines), with trendlines. Two trendlines are shown, the estimated weekly visits for 2020 in the prepandemic and peripandemic (dotted) periods, and the counterfactual scenario (solid) of the predicted number of weekly visits if patterns had continued as they had in the prepandemic period. The x axis weeks represents weeks starting January 1 of each of the 3 study calendar years.

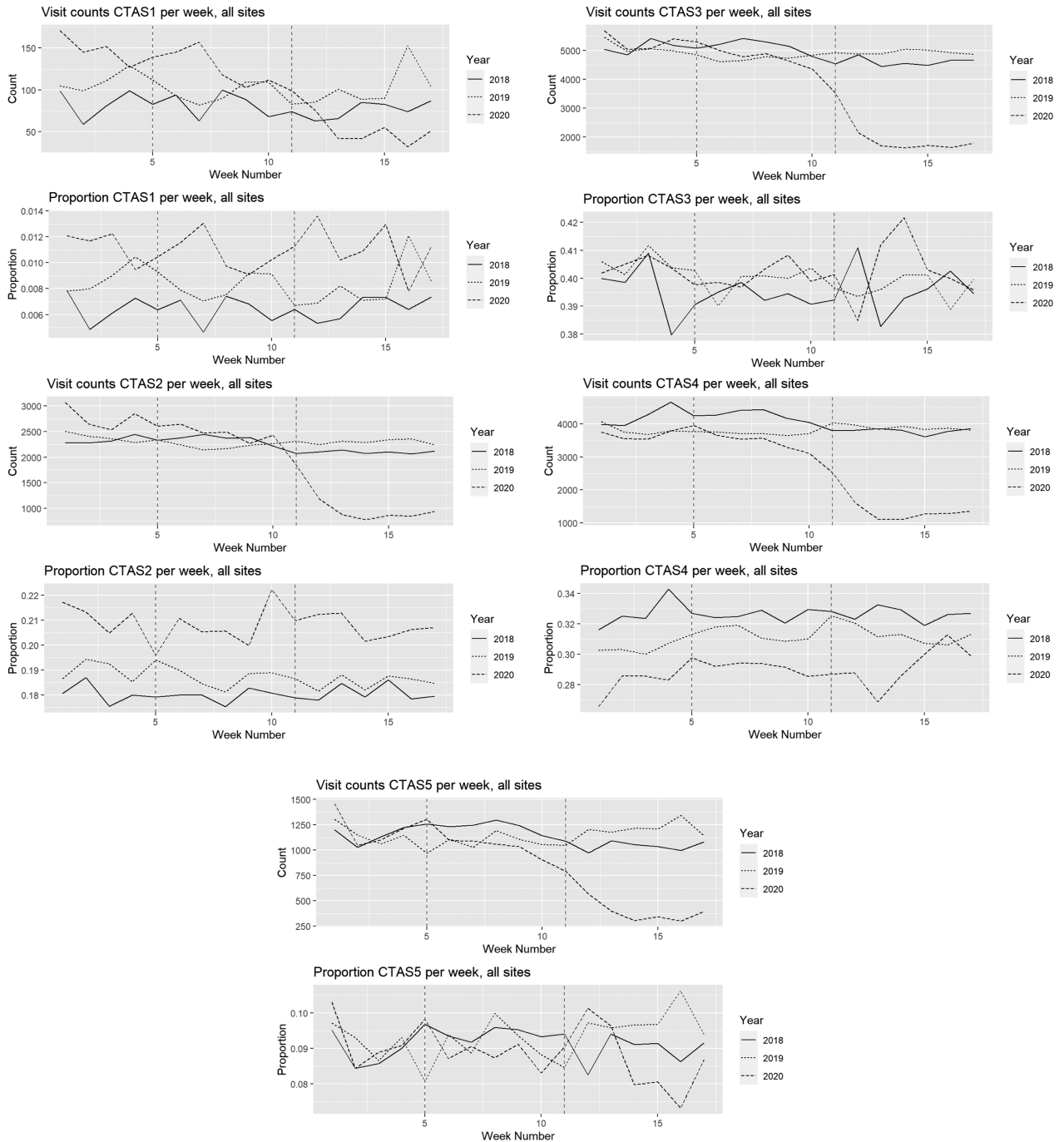


FIGURE 2. Number and proportion of ED visits by PaedCTAS score. The x axis weeks represents weeks starting January 1 of each of the 3 study calendar years.

it did not vary between study periods ($P = 0.15$) (eFig. 2, Supplemental Digital Content, <http://links.lww.com/PEC/A777>).

Mortality

Study year was not associated with the probability of death. Mortality rates per 10,000 ED visits were 3.08, 2.84, and 2.76 in 2018, 2019, and 2020, respectively (OR of death in 2020 compared with 2018, 0.89; 95% CI, 0.60–1.30; $P = 0.82$).

Emergency Department Revisits

The number of ED revisits within 72 hours was reduced during the early-pandemic period (percent change, -55% ; 95% CI, -61% to -49% ; $P < 0.001$). However, the proportion of ED visits associated with a revisit did not differ from the prepandemic period in either the peripandemic (OR, 0.97; 95% CI, 0.93–1.01; $P = 0.14$) or early-pandemic periods (OR, 1.06; 95% CI, 1.00–1.11; $P = 0.05$).

TABLE 2. Changes in Pediatric ED Volumes, Acuity, Patterns, and Outcomes in the Peripandemic Period (Period 2) and Early-Pandemic Period (Period 3) Compared With the Prepandemic Period

	Period	No. Visits			Proportion of Visits		
		% of Baseline	95% CI	P	OR	95% CI	P
Primary outcome							
Total ED visits	2	-3	-12% to +7%	0.52			
	3	-58	-63% to -51%	<0.001			
Secondary outcomes							
PaedCTAS score							
CTAS 1	2	-7	-22% to +12%	0.45	0.96	0.87-1.06	0.45
	3	-56	-66% to -44%	<0.001	1.02	0.90-1.17	0.73
CTAS 2	2	-2	-11% to +9%	0.70	1.01	0.99-1.04	0.30
	3	-56	-61% to -50%	<0.001	1.03	1.00-1.07	0.04
CTAS 3	2	-4	-13% to +6%	0.40	0.99	0.97-1.01	0.34
	3	-58	-63% to -52%	<0.001	1.00	0.97-1.02	0.84
CTAS 4	2	-2	-11% to +9%	0.74	1.02	1.00-1.04	0.14
	3	-58	-63% to -51%	<0.001	1.00	0.97-1.03	0.99
CTAS 5	2	-7	-19% to +6%	0.27	0.96	0.93-0.99	0.01
	3	-61	-67% to -52%	<0.001	0.93	0.89-0.97	0.002
Non-ICU admissions	2	-4	-9% to +2%	0.18	0.99	0.96-1.03	0.74
	3	-41	-45% to -37%	<0.001	1.39	1.32-1.45	<0.001
ICU admissions	2	-1	-16% to +17%	0.94	1.03	0.90-1.17	0.70
	3	-49	-59% to -37%	<0.001	1.20	1.01-1.42	0.04
ED revisits within 72 h	2	-6	-15% to +4%	0.21	0.97	0.93-1.01	0.14
	3	-55	-61% to -49%	<0.001	1.06	1.00-1.11	0.05
Trauma							
1-<10 y	2	-6	-13% to +1%	0.08	0.97	0.94-1.01	0.11
	3	-37.0	-42% to -31%	<0.001	1.51	1.45-1.56	<0.001
≥10 y	2	+4	-10% to +20%	0.60	1.08	1.04-1.12	<0.001
	3	-73	-78% to -66%	<0.001	0.65	0.62-0.69	<0.001
Mental health							
1-<10 y	2	-16	-28% to -2%	0.03	0.87	0.76-1.01	0.06
	3	-60	-67% to -51%	<0.001	0.96	0.81-1.15	0.65
≥10 y	2	-1	-14% to +14%	0.91	1.03	0.98-1.09	0.29
	3	-56	-63% to -47%	<0.001	1.05	0.98-1.12	0.17

CTAS indicates Canadian Triage and Acuity Scale; ICU, intensive care unit.

Trauma

Although the number of trauma-related ED visits by children less than 10 years decreased during the early-pandemic period (percent change from prepandemic period, -37%; 95% CI, -42% to -31%; *P* < 0.001), these visits accounted for a greater proportion of all ED visits (OR, 1.51; 95% CI, 1.45-1.56; *P* < 0.001) (Table 2, Fig. 3). A different pattern was observed among children 10 years or older—the number of trauma-related visits declined in the early-pandemic period (percent change from baseline, -73%; 95% CI, -78% to -66%; *P* < 0.001), and they represented a smaller proportion of ED visits (OR, 0.65; 95% CI, 0.62-0.69; *P* < 0.001).

Mental Health

Although the number of mental health-related ED visits in children less than 10 years declined in the early-pandemic period (percent change, -60%; 95% CI, -67% to -51%; *P* < 0.001), there were no changes in proportional measures. The findings were similar among those 10 years or older. There was a reduction in total number of ED mental health-related visits during the

early-pandemic period relative to the prepandemic period (percent change, -56%; 95% CI, -63% to -47%; *P* < 0.001; Figure 3).

DISCUSSION

In this pan-Canadian study, we found that after the declaration of the COVID pandemic by the WHO in March 2020, the number of ED visits across Canada's network of tertiary-care pediatric centers declined by 58%. Simultaneously, the disease acuity of children brought to the ED increased, with a greater proportion requiring urgent or emergent medical interventions, and patients were more likely to be hospitalized on the wards or ICU. The initial period between the first identified COVID-19 case in Canada (January 2020) and the WHO pandemic declaration (March 2020) was not associated with such changes.

During the first wave of the pandemic, these reductions have been largely attributed to fear of COVID-19 exposure in the hospital setting.^{9,27} A survey conducted in Chicago reported that nearly 25% of caregivers were hesitant to bring their child for ED care when presented with a hypothetical emergency condition.²⁸ In addition, the widespread implementation of physical

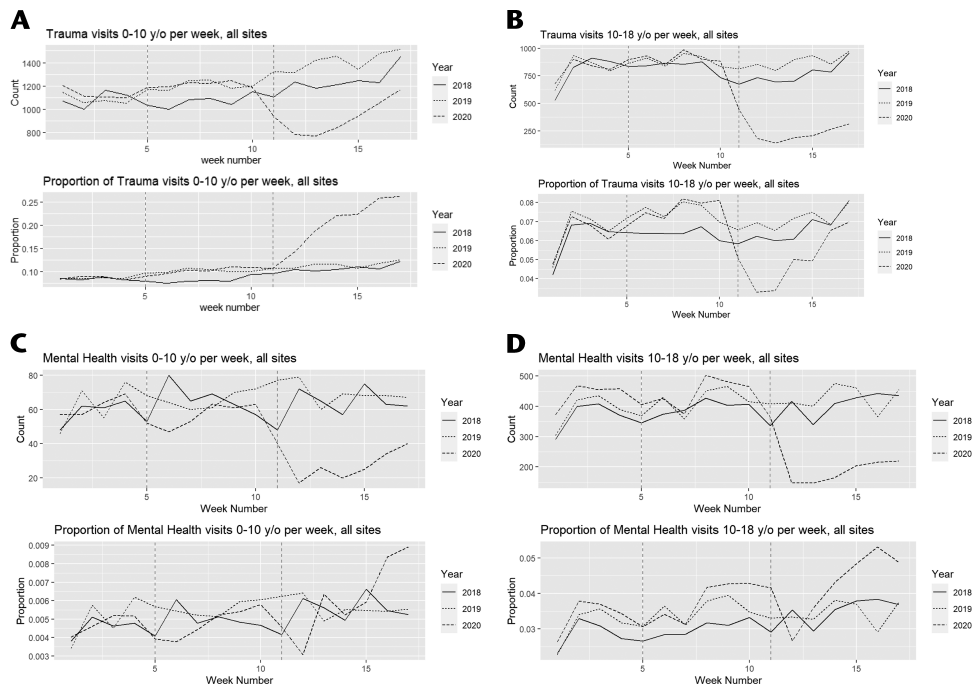


FIGURE 3. Number and proportion of ED visits represented by children presenting for trauma—[(A) <10 years of age; (B) ≥10 years of age] and mental health–related [(C) <10 years of age; (D) ≥10 years of age] concerns. The x axis weeks represents weeks starting January 1 of each of the 3 study calendar years.

distancing and hygiene precautions have further contributed to these reductions.^{29,30} Other system changes in response to COVID-19 such as virtual pediatric ED care may also have played a role.³¹ Nonetheless, the observed 58% decrease from the expected number of pediatric ED visits in our study in the weeks after the WHO pandemic declaration is particularly noteworthy because many primary care offices and other health care settings were closed.

Mounting evidence suggests that delays in emergency care sought by adults during the pandemic have resulted in increased morbidity and mortality for conditions such as stroke^{32,33} and myocardial infarction.³³ Our findings demonstrate that delayed ED presentations are also occurring in the pediatric population, as reflected by an increase in the proportion of children presenting with a higher versus low acuity score (PaedCTAS level II vs PaedCTAS level V), and of those requiring ICU (+20%) or ward (+40%) hospitalization during the early-pandemic period. Similar findings were reported in a single-institution study from the United States, where the proportion of high-acuity visits increased from 50% to 59% ($P < 0.001$).⁸ In a study limited to the province of British Columbia, Canada, that included children seen primarily in general EDs, admission rates increased mainly due to a reduction in the number of low-acuity visits.³⁴ Taken together, it seems that the proportional increase in acuity reflects a reduction in nonacute children brought for ED care.

The changes in social behaviors, workplace, and school routines imposed by stay-at-home orders and lockdowns have led to alterations in the patterns of disease-specific presentations. Notably, we observed a 51% increase in the proportion of children younger than 10 years who were brought to EDs for trauma in the early-pandemic period. Conversely, the proportion of children older than 10 years presenting with trauma declined by 35% during the same period. Decreases in injury-related ED visits have been reported in Latin America,^{32,35} Spain,^{20,35} Ireland,³⁶ United States,⁸ and United Kingdom¹² and were attributed to reductions

in traffic crashes, workplace accidents, and extracurricular activities. We postulate that the increase in trauma-related ED visits in our younger study population may be related to accidents in the home environment, such as falls and burns,³⁷ in contrast to the aforementioned injuries, which are more typical in teenagers. Undersupervision of young children in the home, with limited school attendance, and some caregivers concurrently working from home may have been contributing factors.

Although empirical data are sparse,¹¹ concern has been raised about the potential effect of the COVID-19 pandemic on the mental health of youth.³⁸ In a database study of ~70 million US residents, nearly 1 in 5 patients diagnosed with SARS-CoV-2 infection were also diagnosed with a mental health disorder within 90 days, about one third were first-time psychiatric diagnoses.³⁹ We documented a 56% to 60% decrease in the volume of children who presented for mental health concerns during the COVID pandemic period. This decline is particularly concerning in the context of social isolation, school closures, and restricted access to primary care and youth support and raises questions about the long-term consequences from unaddressed mental health symptoms. In fact, a report from the Centers for Disease Control's National Syndromic Surveillance Program documented a similar decline from mid-March through early April, which was followed by a steady increase through October 2020.⁴⁰ Overall though, from mid-March through October 2020, although average weekly reported total ED visits by children were 43% lower in the National Syndromic Surveillance Program when compared with 2019, the average proportion of pediatric mental health–related ED visits was 44% higher in 2020 compared with 2019.⁴⁰

The COVID-19 pandemic has taught us many lessons, and although no 2 pandemics are alike and it is unlikely that future pandemics will similarly spare children from high-acuity disease, we should still reflect on this experience. First, pediatric ED visits are influenced by public health measures. The measures implemented to curtail the spread of SARS-CoV-2 have virtually eliminated

influenza⁴¹ and bronchiolitis⁴² and, as we have shown, altered the epidemiology of injuries. Second, health care administrative and policy decisions affect the demand for ED care, and rapid adjustments in practice models were required. Lastly, the pandemic altered the public's perception of when ED care should be sought. Although, this does not seem to have led to increased mortality in children, a rare outcome in this population, there seems to be increased morbidity associated with other common diseases such as appendicitis.¹⁰

Several limitations merit mention. Although when planned, our brief study period focusing on the immediate pandemic period, seemed like the ideal design, in retrospect, given the protracted nature of the COVID-19 pandemic, a more prolonged study period would have been ideal. We did not interview patients and families; therefore, elucidation of personal motivations regarding timing of emergency care access is unknown. We focused on pediatric EDs, and the scenario of general ED use by children may be somewhat different. It should be noted that although the higher proportional admission rate may reflect increased acuity, we cannot exclude the possibility that this finding occurred due to Roemer's law—the principle in health care policy that hospital beds tend to be used, which implies that there is a positive relationship between hospital bed availability and inpatient hospitalization rates.⁴³ Lastly, although our findings may not inform the system planning for the second wave of the pandemic, they may prove particularly insightful for system planning for future similar pandemics, which are likely to occur.⁴⁴

In summary, the declaration of the COVID-19 pandemic by the WHO was associated with a profound reduction in the number of children seeking emergency care in Canada's tertiary-care pediatric hospitals, with a concomitant increase in acuity, potentially stemming from delays in accessing care. Children who presented for ED care during the COVID-19 pandemic were sicker and more likely to be hospitalized and require ICU care. Stay-at-home orders and lockdowns were associated with an increased proportion of trauma visits in young children and a marked decrease in children accessing acute mental health care. Awareness of the impact of the COVID pandemic on the physical and mental health of children is of utmost importance. Public health measures must consider the significant impact of COVID-19 on health care-seeking behaviors and outcomes among children.

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