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Research

Routine childhood vaccination rates in an academic family health team before and during the first wave of the COVID-19 pandemic: a pre–post analysis of a retrospective chart review

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Abstract

Background: There has been concern about declining routine vaccination rates during the COVID-19 pandemic. We evaluated the impact of the COVID-19 pandemic on early childhood vaccination rates at 2 sites of an academic family health team in the Greater Toronto Area, Ontario, serving both an urban and suburban patient population.

Methods: We conducted a pre–post analysis of vaccination records from Jan. 1, 2018, to Nov. 30, 2020, for a cohort of children born between Jan. 1, 2018, and Aug. 31, 2020, from the electronic medical record (EMR) of the Mount Sinai Academic Family Health Team (including an urban academic site in Toronto and a suburban community site in Vaughan, Ontario). We estimated the proportion of children receiving timely, delayed or no vaccination for 10 publicly funded vaccines in the Ontario immunization schedule for the pre-COVID-19 (Jan. 1, 2018, to Mar. 16, 2020) and COVID-19 (Mar. 17 to Nov. 30, 2020) pandemic periods. We determined timeliness in accordance with the recommended age of administration, with a 28-day window; we considered vaccines administered after this window to be delayed. We estimated the median time to vaccination for each vaccine and present cumulative incidence curves.

Results: The patient population was balanced between boys (52.4%) and girls (47.6%), with an average age of 18.5 months and representation across low-, middle- and high-income groups. Of the 506 children in our cohort, 422 were up to date with vaccinations (83.4%) by the end of the study period. Comparatively, 308 (83.2%) of the 370 eligible patients were up to date for all required vaccinations by the end of the pre-COVID-19 period. Among children younger than 12 months, vaccination rates were similar in the pre-COVID-19 and COVID-19 pandemic periods. Lower rates of timely vaccination for children between 12 and 18 months of age were amplified during the pandemic. Cumulative incidence curves were suggestive of a decrease in the timeliness of vaccinations in the COVID-19 period for the vaccines administered at 12, 15 and 18 months, compared with the pre-COVID-19 period.

Interpretation: Our local findings suggest a deterioration in the uptake of routine childhood vaccines in children aged 12 to 18 months in the first year of the COVID-19 pandemic. Further study is needed to determine the extent of the vaccination gap in children across Canada, including the impact of subsequent waves of the COVID-19 pandemic.

Childhood vaccination programs are a critical public health intervention that have virtually eliminated previously common and often fatal infectious diseases.[1] In Canada, vaccination programs exist in various forms in each province and territory. In Ontario, publicly funded vaccinations begin at 2 months of age and are largely delivered by family physicians and general pediatricians.

On Mar. 17, 2020, the Ontario government declared a public emergency under the province's *Emergency Management and Civil Protection Act* in response to the COVID-19 pandemic. The province faced 2 key issues: the uncertainty of the supply of personal protective equipment for health care workers and an acute care system that was already facing capacity issues.[2] In the early response to the pandemic, part of the efforts to combat these challenges revolved around a coordinated public campaign urging citizens to stay home except for essential services.

Ontario billing data suggest a substantial decrease in overall patient visits since the emergence of the COVID-19 pandemic.[3] Total visit volumes to family physicians in Ontario were 15% lower in June 2020 than June 2019, inclusive of virtual and in-person visits. Given reports of reduced vaccination rates from other jurisdictions,[4,5] an important question is whether these observed volume decreases have affected routine childhood vaccinations in Ontario.

Competing interests: Milena Forte is vice-chair of the Maternal Newborn Group of the College of Family Physicians of Canada. No other competing interests were declared.

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The objective of this study was to evaluate the impact of the COVID-19 pandemic on vaccine uptake rates in early childhood at 2 sites of a family health team (FHT) in Ontario, an urban academic centre in downtown Toronto and a suburban community site in Vaughan. We investigated the proportion of patients receiving timely (within 28 days of the recommended age of administration), delayed (more than 28 days after the recommended age of administration) or no vaccinations (vaccines not administered during the study period), before and after the start of the COVID-19 pandemic. We also evaluated time to routine vaccination both before and after the start of the COVID-19 pandemic.

Methods

Study design and setting

We performed a pre- and post-analysis on a retrospective chart review of children younger than 2 years old rostered with the Mount Sinai Academic Family Health Team to assess the effects of COVID-19 on vaccination rates from Jan. 1, 2018, to Nov. 30, 2020.

Our FHT combines the expertise and services of an interprofessional team to provide preventive and acute care across the age spectrum (i.e., pediatric, adult and geriatric care), as well as full-service maternity care (including individual and group prenatal, birth and postpartum care), and is affiliated with a large teaching hospital. Our downtown Toronto academic primary care team serves a population of about 12 000 patients and includes family physicians, family medicine residents, nurses and other interprofessional health care providers. Our community site in suburban Vaughan serves about 10 000 patients and its team is composed of a similar interprofessional team, without trainees. Our FHT maintained our usual hours of operation throughout the pandemic, offering both virtual and in-person appointments. Of note, we prioritized and had the capacity to offer uninterrupted routine childhood vaccinations administered by physician and nursing staff, with clinic staff having access to adequate personal protective equipment, infection control and prevention resources, and physical distancing in the clinic space.

Participants

Our patient population of interest was children younger than 2 years of age. Study participants included all patients born between Jan. 1, 2018, and Aug. 31, 2020 (i.e., 2 mo + 28 d before study end point, ensuring all patients could be included in a least 1 comparison). We collected vaccination data until Nov. 30, 2020.

Data sources

We extracted patient demographics (i.e., birth date, sex) and timing of routine childhood vaccinations from the FHT's electronic medical record (EMR). We also extracted the patient's postal code to determine regional income and ethnic density compared to the national average. We mapped postal codes to income quintile and immigrant tercile with geocoded information from Statistics Canada.[6]

We initially extracted semistructured information regarding administration and timing of early childhood vaccinations via the chart review function from the EMR's database of cumulative patient profiles within individual health records. Our biostatistician (C.M.) parsed each immunization string, attached date-format pairs and grouped each administered vaccination into 6 classes based on time-of-administration intervals (i.e., 2 months, 4 months, 6 months, etc.). With this list generated for all patients, we grouped patients into 4 possible groups: those who completed all required vaccinations on time, those who completed all required vaccinations with some delay, those missing at least 1 of their requisite vaccinations or those with no vaccine information recorded in the EMR.

The biostatistician (C.M.) and physicians (A.D., G.S., M.F., N.M.) reviewed patients in the first 2 groups to confirm the correctness of the programming logic compared with the source data in the EMR. For any charts with incomplete vaccination records or no vaccinations recorded, 2 physicians (A.D., G.S.) undertook a secondary manual chart review to identify if the vaccination had, in fact, been given, but was incorrectly documented outside of the cumulative patient profiles. Given the lack of data complexity, simplified clinical workflows for vaccine entry and available resources, each manual chart review was conducted by 1 physician.

Outcomes

We estimated differences before and after the start of the pandemic in the proportion of patients receiving timely vaccine administration (within 28 days of indicated age), delayed vaccine administration (more than 28 days after indicated age) or no immunization for 10 early childhood vaccinations that are publicly funded in Ontario.[7] We excluded rotavirus vaccination as an outcome measure because of the added complexity in data reporting resulting from 2 rotavirus vaccine options available in Ontario, each with differing administration schedules.

In this study, we assumed that the intervention date of the COVID-19 period was Mar. 17, 2020, the date when the province of Ontario declared the COVID-19 pandemic an emergency. Depending on the timing of patient birth date relative to the COVID-19 intervention date, we assigned patients to the pre-COVID-19 group or the COVID-19 group, or declared the patient to be ineligible for the comparison if they were not old enough for the specified vaccination during the study period.

Statistical analysis

We evaluated differences between the pre-COVID-19 and COVID-19 pandemic periods at the level of the vaccination event, with a concrete division between the periods set on Mar. 17, 2020. For a given patient and a given routine vaccination, we included events (timely, delayed or no vaccination) in the pre-COVID-19 period if the planned date of vaccination (based on patient birth date) fell before Mar. 17, 2020. In the event that the planned vaccination date was to occur after Mar. 17, 2020, we counted events toward the COVID-19 period. Each individual patient could contribute data in up to

10 vaccination events over the study period. Depending on date of birth, patients could have all their vaccination events in the pre-COVID-19 period, all their vaccination events in the COVID-19 period or vaccination events in both the pre-COVID-19 and COVID-19 observation periods.

We used descriptive statistics to characterize our study sample. We estimated the percentage of patients receiving timely, delayed or no vaccination for each of the 10 routine vaccinations before and after the start of the COVID-19 pandemic. We calculated 95% confidence intervals (CIs) for each of the estimated percentages using the Clopper–Pearson method. We used the Fisher exact test to test whether the percentage of patients receiving timely, delayed or no vaccination differed in the pre-COVID-19 and COVID-19 periods. We estimated median time to vaccination (and 95% CI) for each of the routine childhood vaccinations, assuming that all unvaccinated children at risk for a given planned routine vaccination were right-censored.

We plotted cumulative incidence functions and used log-rank tests to evaluate differences in time to each of the 10 routine childhood vaccinations in each period. We used a Bonferroni-corrected threshold (0.05 α/20 analyses = 0.0025) for declaring statistical significance of hypothesis tests (chosen as a conservative boundary for maintaining the family-wise error rate of the study).

Ethics approval

Ethics approval was received from the Mount Sinai Hospital Research Ethics Board.

Results

The study included 506 patients, born between Jan. 1, 2018, and Aug. 31, 2020, with at least 1 vaccination event. Table 1 specifies the number of patients in each group for each of the 10 included vaccinations, in accordance with the recommended timing of vaccine administration and the eligible birth date intervals for the pre–post comparison. Patient characteristics are presented in Table 2. The patient population was balanced between boys (52.4%) and girls (47.6%). The average age of the included children as of Nov. 30, 2020, was 18.5 months (median 17.7 mo, interquartile range 10.0–26.6 mo). The oldest child was born Jan. 1, 2018, and the youngest child was born Aug. 29, 2020. The number of patients born in each study month is given in Appendix 1, available at www.cmajopen.ca/content/10/1/E43/suppl/DC1.

Using postal code information, 85 patients (16.8%) resided in low-income regions, 127 (25.1%) resided in high-income regions, and the remaining 291 (57.5%) lived in middle-income regions. Three patients (0.6%) were missing information on regional income. In terms of the cohort's relative ethnic

Table 1: Vaccine-eligible patients in the pre-COVID-19 (Jan. 1, 2018, to Mar. 16, 2020) and COVID-19 (Mar. 17, 2020, to Nov. 30, 2020) groups based on age for selected childhood vaccinations[6]

	Birth date interval		No. of patients		
Age and vaccination	Pre-COVID-19 group	COVID-19 group	Eligible in pre-COVID-19 period	Eligible in COVID-19 period	Ineligible
2 mo, DTaP-IPV-Hib	Jan. 1, 2018 to Jan. 17, 2020	Jan. 17, 2020 to Aug. 31 2020	375	131	0
2 mo, Pneu-C-13	Jan. 1, 2018 to Jan. 17, 2020	Jan. 17, 2020 to Aug. 31, 2020	375	131	0
4 mo, DTaP-IPV-Hib	Jan. 1, 2018 to Nov. 17, 2019	Nov. 17, 2019 to June 30, 2020	348	124	34
4 mo, Pneu-C-13	Jan. 1, 2018 to Nov. 17, 2019	Nov. 17, 2019 to June 30, 2020	348	124	34
6 mo, DTaP-IPV-Hib	Jan. 1, 2018 to Sept.17, 2019	Sept. 17, 2019 to Apr. 30, 2020	315	121	70
12 mo, MMR	Jan. 1, 2018 to Mar. 17, 2019	Mar. 17, 2019 to Oct. 31, 2019	214	127	165
12 mo, Pneu-C-13	Jan. 1, 2018 to Mar. 17, 2019	Mar. 17, 2019 to Oct. 31, 2019	214	127	165
12 mo, Men-C-C	Jan. 1, 2018 to Mar. 17, 2019	Mar. 17, 2019 to Oct. 31, 2019	214	127	165
15 mo, Var	Jan. 1, 2018 to Dec.17, 2018	Dec. 17, 2018 to July 31, 2019	175	99	232
18 mo, DTaP-IPV-Hib	Jan. 1, 2018 to Sept.17, 2018	Sept.17, 2018 to Apr. 31, 2019	129	104	273

Note: DTap-IPV-Hib = diphtheria, tetanus, acellular pertussis, inactivated polio vaccine, *Haemophilus influenzae* type B; Men-C-C = meningococcal conjugate C; MMR = measles, mumps, rubella; Pneu-C-13 = pneumococcal conjugate 13; Var = varicella.

Table 2: Characteristics of study participants, born between Jan. 1, 2018, and Aug. 31, 2020, with at least 1 vaccination

Characteristic	No. (%) of participants* *n* = 506
Sex	
Male	265 (52.4)
Female	241(47.6)
Age, mo	
Mean	18.5
Median (IQR)	17.7 (10.0–26.6)
Birth date, range	Jan. 1, 2018 to Aug. 29, 2020
Regional income†	
Low	127 (25.1)
Middle	291 (57.5)
High	127 (25.1)
Missing	3 (0.6)
Regional ethnic density‡	
Low	89 (17.6)
Middle	267 (52.8)
High	140 (27.7)
Missing	10 (1.9)

Note: IQR = interquartile range.
*Unless indicated otherwise.
†As determined using postal code information.
‡Density of visible minorities as compared with national average.

composition, 89 (17.6%) patients resided in regions with a density of visible minorities below national averages, 267 (52.8%) patients resided in regions similar to national averages, and 140 (27.7%) resided in regions with a higher density than the national average. Ten patients (2.0%) were missing information.

Table 3 illustrates the percentage of patients receiving timely, delayed or no vaccination pre-COVID-19 versus during COVID-19 for each recommended vaccination. Each individual patient was included in varying numbers of comparisons depending on their birth date. Median time to vaccination is presented in Table 4. Cumulative incidence functions for each routine childhood vaccination in each study period are illustrated in Appendix 2, available at www.cmajopen.ca/content/10/1/E43/suppl/DC1.

For the early childhood vaccinations recommended at 2, 4 and 6 months of age, we observed similar rates of timeliness of vaccination or up-to-date status across the 2 time periods. For the later vaccines administered at 12, 15 and 18 months, the differences were statistically significant at a 0.05 α level, but not at the 0.0025 Bonferroni-corrected level).

Overall, at the end of the study period (Nov. 30, 2020), 422 (83.4%) of the 506 patients were up to date for all of their required vaccinations. Comparatively, on Mar. 17, 2020, 308 (83.2%) of the 370 eligible patients were up to date for all of their required vaccinations.

Interpretation

Our findings showed that timeliness and up-to-date status of early childhood vaccination in the 2 time periods (pre-COVID-19 and COVID-19) differed by time of administration interval in our FHT. Timeliness and up-to-date status were similar pre-COVID-19 and during COVID-19 for the early vaccinations (at ages 2, 4 and 6 months), and the differences we observed for the later vaccinations (at ages 12 and 18 months) were suggestive of declines in timeliness of vaccination and up-to-date status in the COVID-19 period compared with the pre-COVID-19 period.

COVID-19 poses threats to public health and health care systems worldwide, with governments implementing multifaceted restrictions to curb the spread of SARS-CoV-2 and lessen the burden on health care systems.[8] Although these mitigation strategies are important, concerns have been raised about their unintended consequences, such as the disruption to the provision of routine primary care, including vaccine delivery. Immunization against vaccine-preventable illness is a cornerstone of preventive medicine in primary care. Several key organizations, including the Canadian Paediatric Society, the National Advisory Committee on Immunization and Public Health Ontario, emphasized adherence to recommended vaccination schedules, irrespective of pandemic restrictions.[9–11] Our study evaluated childhood vaccination data in the time of COVID-19 from the perspective of Ontario primary care.

The finding of lower vaccine completion rates among children aged 12 to 18 months in the pandemic period may indicate a particularly at-risk group for delayed or missing vaccinations. Despite the lack of statistical significance, we found a lag in vaccination rates among children aged 6 months and older. We observed that, even before the pandemic, there was attrition in vaccination rates in these older age groups, though this seemed to be amplified with the start of the COVID-19 pandemic. Although it is reassuring that many children do eventually "catch up," it may be clinically significant that delayed vaccination rates increased in the COVID-19 period, ranging from 5% to 15%, depending on the age group. There may be several explanations for the difference in timeliness of vaccination between younger and older infants. We postulate that 1 reason may be that parents feel less urgency to have vaccines administered in older children because they are partially vaccinated already. In reality, in the event of an outbreak, these partially vaccinated children are at greater risk of morbidity from a vaccine-preventable illness than those who are up to date with their vaccinations.[12]

The Public Health Agency of Canada routinely monitors childhood vaccination coverage in Canada through the childhood National Vaccination Coverage Survey (cNICS) and declared a national vaccination goal of 95% for each childhood vaccine.[13] Our FHT's vaccination rates seemed on par with cNICS's Ontario data for 2017.[13] Research from Alberta and Nova Scotia assessed the timeliness of routine childhood vaccinations and showed that the 12- and 18-month vaccinations had the lowest proportion of children receiving timely doses.[14,15] Our observations appear to be consistent with these findings in both the pre-pandemic and pandemic periods.

Table 3: Proportion of patients receiving timely, delayed or no vaccination in the pre-COVID-19 (Jan. 1, 2018, to Mar. 16, 2020) and COVID-19 (Mar. 17, 2020, to Nov. 30, 2020) periods

	Pre-COVID-19				COVID-19				
Age and vaccination	No. of eligible patients	No. (%, CI) vaccinated on time	No. (%, CI) delayed vaccination	No. (%, CI) not vaccinated	No. of eligible patients	No. (%, CI) vaccinated on time	No. (%, CI) delayed vaccination	No. (%, CI) not vaccinated	*p* value*
2 mo, DTaP-IPV-Hib	375	355 (94.67, 91.88–96.71)	14 (3.73, 2.06–6.18)	6 (1.60, 0.59–3.45)	131	124 (94.66, 89.30–97.82)	6 (4.58, 1.70–9.70)	1 (0.76, 0.02–4.18)	0.7586
2 mo, Pneu-C-13	375	352 (93.87, 90.94–96.07)	13 (3.47, 1.86–5.86)	10 (2.67, (1.29–4.85)	131	124 (94.66, 89.30–97.82)	6 (4.58, 1.70–9.70)	1 (0.76, 0.02–4.18)	0.3913
4 mo, DTaP-IPV-Hib	330	310 (93.94, 90.79–96.26)	18 (5.45, 3.26–8.48)	2 (0.61, 0.07–2.17)	116	113 (97.41, 92.63–99.46)	2 (1.72, 0.21–6.09)	1 (0.86, 0.02–4.71)	0.1811
4 mo, Pneu-C-13	328	311 (94.82, 91.83–96.95)	16 (4.88, 2.81–7.80)	1 (0.30, (0.01–1.69)	115	111 (96.52, 91.33–99.04)	2 (1.74, 0.21–6.14)	2 (1.74, 0.21–6.14)	0.0875
6 mo, DTaP-IPV-Hib	280	259 (92.50, 88.76–95.30)	19 (6.79, 4.13–10.39)	2 (0.71, 0.09–2.56)	108	93 (86.11, 78.13–92.01)	10 (9.26 (4.53–16.37)	5 (4.63, 1.52–10.47)	0.024
12 mo, MMR	214	174 (81.31, 75.43–86.30)	27 (12.62, 8.48–17.82)	13 (6.07, 3.27–10.16)	127	88 (69.29, 60.49–77.17)	24 (18.90, 12.50–26.80)	15 (11.81, 6.76–18.73)	0.0321
12 mo, Pneu-C-13	188	160 (85.11, 79.20–89.87)	20 (10.64, 6.62–15.95)	8 (4.26, 1.85–8.21)	117	84 (71.79, 62.73–79.72)	21 (17.95, 11.47–26.12)	12 (10.26, 5.41–17.23)	0.0148
12 mo, Men-C-C	214	173 (80.84, 74.92–85.89)	29 (13.55, 9.27–18.88)	12 (5.61, 2.93–9.59)	127	84 (66.14, 57.21–74.30)	26 (20.47, 13.83–28.54)	17 (13.39, 8.00–20.56)	0.0063
15 mo, Var	175	112 (64.00, 56.41–71.10)	43 (24.57, 18.39–31.64)	20 (11.43, 7.12–17.10)	99	52 (52.53, 42.24–62.66)	24 (24.24, 16.19–33.89)	23 (23.23, 15.33–32.79)	0.0324
18 mo, DTaP-IPV-Hib	100	73 (73.00, 63.20–81.39)	20 (20.00, 12.67–29.18)	7 (7.00, 2.86–13.89)	91	56 (61.54, 50.75–71.55)	23 (25.27, 16.75–35.47)	12 (13.19, 7.00–21.90)	0.1969

Note: CI = confidence interval; DTaP-IPV-Hib = diphtheria, tetanus, acellular pertussis, inactivated polio vaccine *Haemophilus influenzae* type B; Men-C-C = meningococcal conjugate C; MMR = measles, mumps, rubella; Pneu-C-13 = pneumococcal conjugate 13; Var = varicella.
*Calculated using Fisher exact test to assess changes in vaccination uptake pre-COVID-19 versus during COVID-19.

Reasons for incomplete vaccine coverage in children, before the COVID-19 pandemic have received much attention in the literature.[16,17] Our study was not designed to probe into specific factors that may account for reductions in childhood vaccination rates. Rather, we aimed to report early childhood vaccination rates during the COVID-19 pandemic. The observation that the 12-to-18-month age group had less than ideal vaccination rates both before and during the pandemic, as well as increased delayed vaccinations in the COVID-19 period, suggests that this group may represent a high-yield target for improving overall vaccination rates.

Some jurisdictions in the United States have reported declining early childhood vaccination rates as a result of COVID-19.[4,5] A large study, based at a multisite primary care network in Columbus, Ohio, reported declining vaccination rates from existing low rates at baseline. Although other areas, such as New York state, noted a rebound in vaccination rates after a proactive effort to encourage vaccinations,[18] the similarity in reported trends is concerning. The literature suggests that a combination of service provision and service use factors affected rates of vaccine uptake during the pandemic.[18] Service provision factors include the disruption or suspension of programs, workforce shortages from redeployments related to COVID-19, provider illness, inadequate supply of personal protective equipment or materials for infection prevention and control, and disruptions of vaccine supply chains because of production or border restrictions.[19]

In our clinical setting, we were fortunately unaffected by these service provision barriers and were uninterrupted in our ability to offer and prioritize in-person visits for early childhood vaccinations. Therefore, our clinical environment may have represented one of several local "best-case scenarios." Our findings lead us to postulate that service use factors may have had more of a contributory role in the reduced uptake of vaccines we observed during the pandemic. By addressing these factors, there may be ways to mitigate reduced vaccination rates in the context of COVID-19 and, perhaps, to improve rates overall.[19] We should continue to emphasize timely vaccinations across all age groups. Given public fears of COVID-19, and potential confusion regarding evolving public health messages, clear and proactive education for parents becomes vital. Workflows that facilitate timely vaccinations can be implemented, and may include the flagging of missing vaccinations on the cumulative patient profile and automated identification of these patients in the EMR to book appointments.

Table 4: Median time to vaccination for each of the routine childhood vaccinations in the pre-COVID-19 (Jan. 1, 2018, to Mar. 16, 2020) and COVID-19 (Mar. 17 to Nov. 30, 2020) periods

	Pre-COVID-19			COVID-19			
Age and vaccination	No. of eligible patients	No. of vaccinations	Median (95% CI) time to vaccination, mo	No. of eligible patients	No. of vaccinations	Median (95% CI) time to vaccination, mo	*p* value*
2 mo, DTaP-IPV-Hib	375	369	2.07 (2.07–2.10)	131	130	2.10 (2.07–2.14)	0.9453
2 mo, Pneu-C-13	375	365	2.07 (2.07–2.10)	131	130	2.10 (2.07–2.14)	0.9452
4 mo, DTaP-IPV-Hib	330	328	4.14 (4.14–4.18)	116	115	4.14 (4.11–4.21)	0.4203
4 mo, Pneu-C-13	328	327	4.14 (4.14–4.18)	115	113	4.14 (4.11–4.21)	0.4794
6 mo, DTaP-IPV-Hib	280	278	6.18 (6.15–6.21)	108	103	6.25 (6.18–6.35)	0.0054
12 mo, MMR	214	201	12.2 (12.2–12.3)	127	112	12.3 (12.2–12.4)	0.0534
12 mo, Pneu-C-13	188	180	12.3 (12.2–12.4)	117	105	12.3 (12.2–12.4)	0.0892
12 mo, Men-C-C	214	202	12.3 (12.2–12.4)	127	110	12.4 (12.3–12.5)	0.0072
15 mo, Var	175	155	15.5 (15.3–15.7)	99	76	15.7 (15.5–17.3)	0.0391
18 mo, DTaP-IPV-Hib	100	93	18.4 (18.2–18.6)	91	79	18.6 (18.4–18.9)	0.1093

Note: CI = confidence interval; DTaP-IPV-Hib = diphtheria, tetanus, pertussis, polio, *Haemophilus influenzae* type B; Men-C-C = meningococcal conjugate C; MMR = measles, mumps, rubella; Pneu-C-13 = pneumococcal conjugate 13; Var = varicella.
*Calculated using Kaplan–Meier test to assess differences in each of the routine childhood vaccination's cumulative incidence functions pre-COVID-19 versus during COVID-19.

Limitations

We recognize that our study, like many retrospective chart reviews, has limitations. The inconsistency and potential for error during documentation in EMRs is well known.[20] Clinicians have different templates and systems in which they like to document, further increasing the heterogeneity and difficulties in analyzing this type of data. Another limitation with this study includes the use of 1 clinician in data extraction of manual chart reviews, which represented the minority of cases. At our 2 clinic sites, we mitigated this issue by enforcing a built-in vaccination entry system to document all vaccinations with all care providers. Another limitation may be the difficulty in establishing a clear division between the COVID-19 and pre-COVID-19 periods as patients in family medicine are under continuous rather than episodic care. This limitation may affect our attempts to present a conclusive comparison between both time periods.

Since service provision factors did not substantially change during the 2 time periods at our FHT, our data may underestimate the effect of the COVID-19 pandemic on vaccination rates and may not be representative of the broader context. It is also worth noting that the study period did not include the period of the highest COVID-19 case numbers in Ontario to date, which happened after the close of the data collection.[21] It is possible that the decline in vaccination rates we observed was more pronounced during later waves of the pandemic, although we cannot say that conclusively without evaluating that data.

Finally, caution must be taken when attempting to generalize the results of this study to other practice settings. Our study setting includes 2 clinic sites of an academic FHT, one in downtown Toronto and the other in suburban Vaughan. Although our patient population likely differs from those of smaller Ontario communities, as well as from other areas in Canada, the available demographic information about our cohort suggests there is adequate representation across a broad area of the Greater Toronto Area. Furthermore, we did not evaluate the effects of seasonality, given the lack of clear guidance available in the literature for a standardized period in which a child can be considered late for vaccination,[14] and this remains a potential future area of exploration. Further research would need to be undertaken to understand the impact of the pandemic on vaccination rates in other geographical areas of Canada and around the globe.

Conclusion

Our findings suggest that, in our setting, the COVID-19 pandemic has led to a deterioration in the uptake of routine childhood vaccines. Like the rest of Canada, our routine childhood vaccination rates are still suboptimal and their drivers are complicated, even in nonpandemic circumstances. From our data, the lower rates in 12- to 18-month-old children represent a potentially high-yield target for interventions. Improving vaccination rates will be important during COVID-19, as a developing cohort of children with less protection against vaccine-preventable illnesses could further burden an already strained public health system.

References

1. Orenstein WA, Ahmedb R. Simply put: vaccination saves lives. *Proc Natl Acad Sci U S A* 2017;114:4031-3.
2. Ontario enacts declaration of emergency to protect the public: significantly enhanced measures will help contain spread of COVID-19 [news release]. Toronto: Office of the Premier of Ontario; 2020 Mar. 17. Available: https://news.ontario.ca/en/release/56356/ontario-enacts-declaration-of-emergency-to-protect-the-public (accessed 2021 July 11).
3. How COVID-19 affected physician services. Vol. 53. Ottawa: Canadian Institute for Health Information; 2020. Available: https://www.cihi.ca/en/covid-19-resources/impact-of-covid-19-on-canadas-health-care-systems/physician-services (accessed 2021 July 11).
4. Bramer CA, Kimmins LM, Swanson R, et al. Decline in child vaccination coverage during the COVID-19 pandemic — Michigan Care Improvement Registry, May 2016–May 2020. *MMWR Morb Mortal Wkly Rep* 2020;69:630-1.
5. Bode SM, Gowda C, Mangini M, et al. COVID-19 and primary measles vaccination rates in a large primary care network. *Pediatrics* 2021;147:e2020035576. doi: 10.1542/peds.2020-035576.
6. *Postal Code Conversion File Plus (PCCF+) Version 6A, reference guide*. Ottawa: Statistics Canada; 2013.
7. Publicly funded immunization schedules for Ontario. Toronto: Ontario Ministry of Health; 2021.
8. Tam T. Chief Public Health Officer of Canada's report on the state of public health in Canada 2020. From risk to resilience: an equity approach to COVID-19. Ottawa: Public Health Agency of Canada; 2020. Available: https://www.canada.ca/en/public-health/corporate/publications/chief-public-health-officer-reports-state-public-health-canada/from-risk-resilience-equity-approach-covid-19.html (accessed 2021 June 25).
9. Stick to immunization schedule during the COVID-19 pandemic, paediatricians urge [media release]. Ottawa: Canadian Paediatric Society; 2020 Apr. 30. Available: https://cps.ca/media/stick-to-immunization-schedule-during-the-covid-19-pandemic (accessed 2021 June 22).
10. Guidance for immunization services during COVID-19, version 1. Toronto: Ontario Ministry of Health; 2020. Available: http://www.health.gov.on.ca/en/pro/programs/publichealth/coronavirus/docs/Immunization_Services_during_COVID-19_08-26-2020.pdf (accessed 2021 June 23).
11. Interim guidance on continuity of immunization programs during the COVID-19 pandemic. National Advisory Committee of Vaccinations; updated 2020 May 13. Available: https://www.canada.ca/en/public-health/services/immunization/national-advisory-committee-on-immunization-naci/interim-guidance-immunization-programs-during-covid-19-pandemic.html (accessed 2021 June 25).
12. Brown C. Measles resurgence comes to Canada. *CMAJ* 2019;191:E319.
13. Vaccine coverage in Canadian children: results from the 2017 Childhood National Immunization Coverage Survey (cNICS). Ottawa: Public Health Agency of Canada; 2019. Cat no HP37-31E-PDF. Available: https://www.canada.ca/en/public-health/services/publications/healthy-living/2017-vaccine-uptake-canadian-children-survey.html#tbl2 (accessed 2021 June 23).
14. Saini V, MacDonald SE, McNeil DA, et al. Timeliness and completeness of routine childhood vaccinations in children by two years of age in Alberta, Canada. *Can J Public Health* 2017;108:e124-8.
15. Dummer TJB, Cui Y, Strang R, et al. Immunization completeness of children under two years of age in Nova Scotia, Canada. *Can J Public Health* 2012;103:e363-7.
16. Scheifele DW, Halperin SA, Bettinger JA. Childhood immunization rates in Canada are too low: UNICEF. *Paediatr Child Health* 2014;19:237-8.
17. MacDonald NE. The long and winding road to improving immunization rates: sharing best practices in Canada. *Can Commun Dis Rep* 2016;42:243-5.
18. Langdon-Embry M, Papadouka V, Cheng I, et al. Notes from the field: rebound in routine childhood vaccine administration following decline during the COVID-19 pandemic — New York City, March 1–June 27, 2020. MMWR *Morb Mortal Wkly Rep* 2020;69:999-1001.
19. Olorunsaiye CZ, Yusuf KK, Reinhart K, et al. COVID-19 and child vaccination: a systematic approach to closing the immunization gap. *Int J MCH AIDS* 2020;9:381-5.
20. Cowie MR, Blomster JI, Curtis LH, et al. Electronic health records to facilitate clinical research. *Clin Res Cardiol* 2017;106:1-9.
21. *Ontario COVID-19 data tool*. Toronto: Public Health Ontario. Available: www.publichealthontario.ca/en/data-and-analysis/infectious-disease/covid-19-data-surveillance/covid-19-data-tool (accessed 2021 Jan. 5).

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