Household Transmission Dynamics of Asymptomatic SARS-CoV-2–Infected Children: A Multinational, Controlled Case-Ascertained Prospective Study

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Background. Asymptomatic SARS-CoV-2 infection in children is highly prevalent but its acute and chronic implications have been minimally described.

Methods. In this controlled case-ascertained household transmission study, we recruited asymptomatic children <18 years with SARS-CoV-2 nucleic acid testing performed at 12 tertiary care pediatric institutions in Canada and the United States. We attempted to recruit all test-positive children and 1 to 3 test-negative, site-matched controls. After 14 days' follow-up we assessed the clinical (ie, symptomatic) and combined (ie, test-positive, or symptomatic) secondary attack rates (SARs) among household contacts. Additionally, post–COVID-19 condition (PCC) was assessed in SARS-CoV-2–positive participating children after 90 days' follow-up.

Results. A total of 111 test-positive and 256 SARS-CoV-2 test-negative asymptomatic children were enrolled between January 2021 and April 2022. After 14 days, excluding households with co-primary cases, the clinical SAR among household contacts of SARS-CoV-2–positive and –negative index children was 10.6% (19/179; 95% CI: 6.5%–16.1%) and 2.0% (13/663; 95% CI: 1.0%–3.3%), respectively (relative risk = 5.4; 95% CI: 2.7–10.7). In households with a SARS-CoV-2–positive index child, age <5 years, being pre-symptomatic (ie, developed symptoms after test), and testing positive during Omicron and Delta circulation periods (vs earlier) were associated with increased clinical and combined SARs among household contacts. Among 77 asymptomatic SARS-CoV-2–infected children with 90-day follow-up, 6 (7.8%; 95% CI: 2.9%–16.2%) reported PCC.

Conclusions. Asymptomatic SARS-CoV-2–infected children, especially those <5 years, are important contributors to household transmission, with 1 in 10 exposed household contacts developing symptomatic illness within 14 days. Asymptomatic SARS-CoV-2–infected children may develop PCC.

Keywords. asymptomatic SARS-CoV-2; children; household transmission; prospective cohort; post-COVID-19 condition.

The role of children in severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) household transmission has been poorly quantified. Early meta-analyses reported that children were infrequently the index case in household clusters, with limited transmission to household contacts [1]. While recent studies have identified symptomatic children as important contributors to household transmission [2–6], studies of asymptomatic pediatric index cases have included few participants or have not presented results of this population separately [4, 5, 7–10].

Approximately one-third of all documented SARS-CoV-2 infections are asymptomatic [11–13], and the true proportion of asymptomatic infections is likely higher [14, 15]. Moreover, although the risk of developing post–coronavirus disease 2019 (COVID-19) condition (PCC) or "long COVID" in asymptomatically infected adults is estimated to be 20% [16], the natural history of asymptomatic SARS-CoV-2 infection in children is poorly characterized. Only a handful of studies have reported on PCC in children with asymptomatic SARS-CoV-2 infection, with risk estimates ranging from 0% to 27% [17–20]. Until these risks are better clarified, asymptomatic infections, which are common with the Omicron variant, cannot be considered benign [21].

The SARS-CoV-2 virus is expected to become an endemic infectious disease in humans [22]. Although the COVID-19 pandemic is no longer considered a public health emergency of international concern, pediatric COVID-19 hospitalizations and coinfections in the United States are increasing [23, 24]. Our knowledge of how COVID-19 pandemic control measures have impacted children will surely influence future policy. However, these decisions need to also be informed by the acute and chronic impacts of pediatric SARS-CoV-2 infection. To fill this knowledge gap, we aimed to quantify the risk of transmission from infected asymptomatic children to their household contacts within 14 days of testing positive for SARS-CoV-2 and to identify associated risk factors. We also sought to estimate the risk of PCC in asymptomatic, acutely infected children.

METHODS

Study Design and Recruitment
We conducted a controlled, case-ascertained, 14-day household transmission study of asymptomatic SARS-CoV-2–infected and noninfected children. We also prospectively followed SARS-CoV-2–infected participants for 90 days. Children under 18 years of age without COVID-19 symptoms (ie, fever, cough, difficulty breathing, fatigue/weakness, myalgias, chills, feeling very unwell, sore throat, rhinorrhea, vomiting, diarrhea, conjunctivitis, headache, anosmia, ageusia, rash) within the preceding 24 hours who were tested for SARS-CoV-2 infection because of a known positive non-household contact, or as part of standard hospital screening procedures, were eligible if they had at least 1 household contact. Household contact was defined as anyone who slept at least 1 night in the household from 2

weeks prior and until 2 weeks after the day of the participating child's SARS-CoV-2 test. Children tested for SARS-CoV-2 via a nucleic acid amplification test (NAAT) were identified and recruited from emergency departments or other hospital-based outpatient/ambulatory settings at 12 pediatric tertiary hospitals in Canada and the United States. For each enrolled SARS-CoV-2–positive child, research personnel attempted to enroll 1–3 asymptomatic children at the same site who tested negative for SARS-CoV-2. After test results were received (within 5 days of testing), a research assistant contacted the legal guardians of potentially eligible children to confirm eligibility; all participants provided written or verbal informed consent and/or assent prior to study activities. Protocols and procedures were approved by the institutional review boards at all study sites.

Data Collection
Baseline data, including demographic characteristics, past medical history, reason for the initial hospital visit, and risk factors for SARS-CoV-2 infection within the previous 14 days, were collected in person, via telephone, or electronic survey, as per participant preference. Fourteen days following SARS-CoV-2 testing, participants were asked for the number of persons in the household and their relationship to the participating child. At that time, all household contacts were asked about symptoms experienced (with onset dates) and the results of any SARS-CoV-2 tests in the 14-day time periods prior to and following the participating child's test, as well as prior known SARS-CoV-2 infection and vaccination status. Data related to the initial hospital visit and any visits occurring in the subsequent 14 days were extracted from participant's medical records. Ninety days following the initial SARS-CoV-2 test, we administered a final questionnaire for SARS-CoV-2–positive participants regarding PCC.

Viral Load Quantification and Variant Identification
Participating sites were asked to send SARS-CoV-2–positive nasopharyngeal swabs to ProvLab Alberta (University of Alberta, Edmonton, Canada) for viral load quantification and COVID-19 variant identification [25]. Further details are provided in Supplementary Text 1. Viral load was reported as genome copies/mL of sample and, for descriptive analysis, they were categorized as less than 4, 4 to less than 6, and 6 or more $\log_{10}$ copies/mL.

Definitions
Hereafter, we refer to households as either exposed or unexposed, depending on the presence/absence of a SARS-CoV-2–positive pediatric participant at the time of enrollment. SARS-CoV-2–positive children were considered the household index case if no other household contacts had COVID-19 symptoms or a positive SARS-CoV-2 test in the 14 days prior to, and until 24 hours after (ie, co-primary case), their test. Households

not fulfilling these criteria (ie, contact with symptoms or positive test within the mentioned time period) were excluded from the primary analysis. For comparison purposes, when the participating child was SARS-CoV-2 negative, the same criteria were applied to identify unexposed households without other known active cases of infectious illness at the time of enrollment. Participants were considered pre-symptomatic if they developed symptoms during the 14-day follow-up. We categorized participants by typical school-age groupings: younger than 5 years, 5 to younger than 13 years, and 13 to younger than 18 years. Household contact age was categorized as younger than 18 years, 18 to younger than 50 years, and 50 years or older. We categorized the length of hospitalization as follows: none (ie, discharged within 24 hours), 24 hours or longer, or unknown. SARS-CoV-2 vaccination status was classified as none or 1 or more dose (ie, any vaccination received). Based on publicly available Canadian data [26], which were analogous to US data [27], participants enrolled from 31 January 2021 (enrollment start) until 30 June 2021, 1 July 2021 to 19 December 2021, and from 21 December 2021 to 22 April 2022 (enrollment end) were classified as being infected during periods of mixed (ie Alpha/other), Delta, and Omicron variant-of-concern (VoC) circulation, respectively.

Participating children were considered lost to follow-up if 3 consecutive attempts to reach out to legal guardians were unsuccessful; 90-day follow-up was attempted regardless of 14-day loss-to-follow-up. As per the World Health Organization consensus definition for children and adolescents, we defined PCC for asymptomatic SARS-CoV-2–infected children as symptoms persistent for at least 2 months with onset occurring within 3 months of confirmed infection [28]. We also considered children to have PCC if they reported a newly diagnosed syndrome or chronic condition since they were tested for SARS-CoV-2 [19].

Outcomes
Primary
The clinical secondary attack rate (SAR) was the proportion of household contacts who became clinical secondary cases (ie, developed symptoms) during the 14-day follow-up period. As has been done with influenza [29, 30], we assumed that, if an acute illness developed in a household contact more than 24 hours after the index child tested positive for SARS-CoV-2, the household contact was infected with SARS-CoV-2 as a "secondary case," even though directionality cannot be assigned with certainty. The combined SAR consisted of clinical secondary cases plus asymptomatic household contacts who reported a positive SARS-CoV-2 test during follow-up at least 24 hours after the child's SAR-CoV-2 test. The clinical SAR, rather than the combined SAR, was selected for the primary comparisons of transmission in exposed and unexposed households as SARS-CoV-2 testing of household contacts in exposed households was more likely to occur and thus bias our findings. On the other hand,

the combined SAR was used for all unadjusted and adjusted analyses that were restricted to exposed households only.

Secondary
The secondary outcome was PCC after 90 days of follow-up.

Statistical Analysis
The characteristics of SARS-CoV-2–positive and –negative participants, and those who completed follow-up versus those lost to follow-up, were compared using chi-square tests or Fisher's exact tests, as appropriate. Viral loads between pre-symptomatic and asymptomatic SARS-CoV-2–positive children were compared using an exact 2-sample Wilcoxon rank-sum test. The proportion of SARS-CoV-2–positive children who developed PCC was estimated along with 95% confidence intervals (CIs).

Unadjusted relative risks (RRs) were calculated to compare household clinical and combined SARs based on the participating child's SARS-CoV-2 status and the household contact's age category. Unadjusted subgroup analysis further generated RRs for household transmission among exposed households after stratifying by a priori specified factors—index child's age, symptom status after 14 days' follow-up (ie, asymptomatic vs pre-symptomatic), hospitalization length, and vaccination status. For exposed households, a log Poisson generalized estimating equation (GEE) model with robust standard errors [31], accounting for household clustering, was built to generate adjusted incidence rate ratios of risk factors for household contacts becoming secondary cases during the 14-day follow-up. This model was first fitted for all household contacts, with backwards selection of variables based on significance within, and influence on, model estimates. To further examine the influence of the child's vaccination status on transmission, the final model variable selection was applied to the subset of households for whom the index SARS-CoV-2–positive child was at least 5 years old, as this was the lower age limit for vaccination during the study period.

All statistical tests were 2-sided, and P values < .05 were considered significant. Stata IC 16.1 (StataCorp LLC, College Station, TX, USA) was used for all analysis and graphics.

RESULTS
We included 111 asymptomatic SARS-CoV-2 test-positive and 256 asymptomatic test-negative children; 14-day follow-up was completed for 68.5% (n = 76) and 77.3% (n = 198) of participants in these groups, respectively (Figure 1). SARS-CoV-2–positive and –negative children had similar baseline characteristics, except that test-positive children were more likely to report a SARS-CoV-2–positive close contact in the previous 14 days (Table 1, Supplementary Table 1a and 1b). Children lost to follow-up were more likely to be younger than 5 years of age (Supplementary Table 2). We observed that some risk factors for acquiring SARS-CoV-2, including school
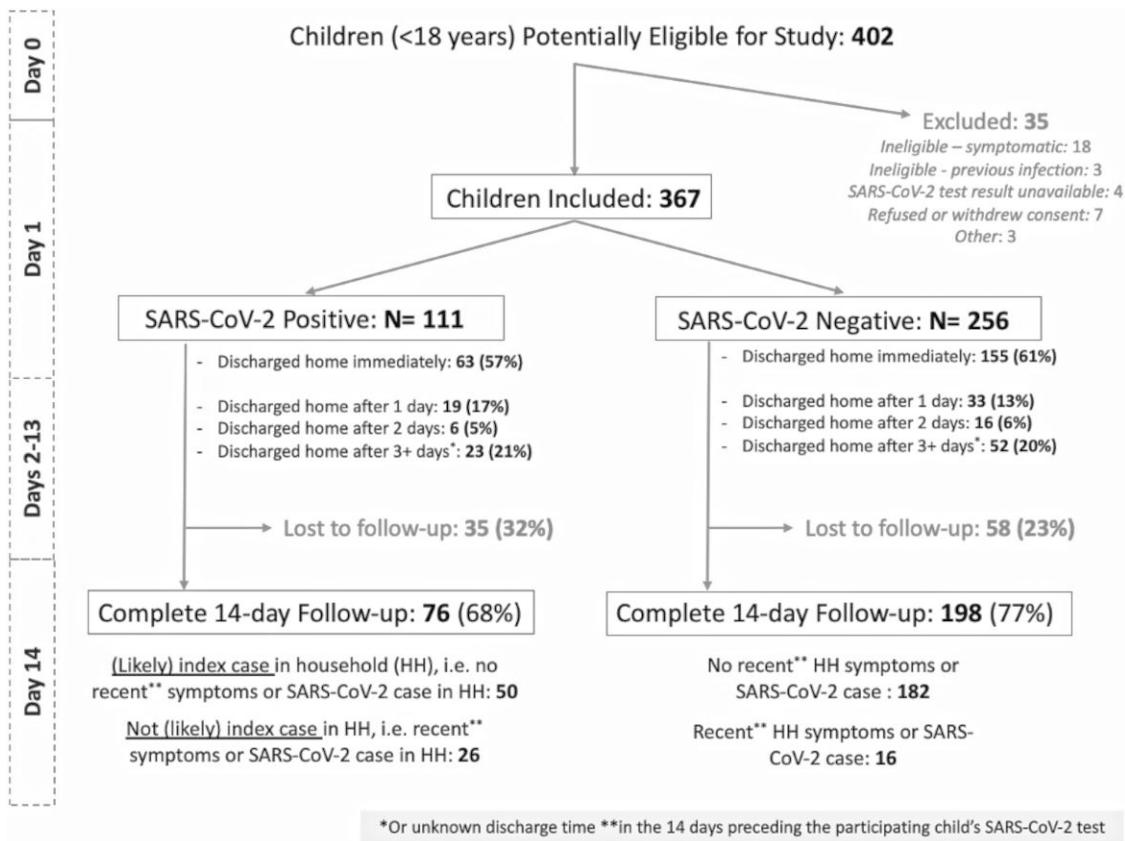
Figure 1. Follow-up of pediatric asymptomatic SARS-CoV-2–positive and –negative participants until 14 days after testing. Abbreviation: SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

and daycare attendance and public transit use, increased in later pandemic stages (Supplementary Table 3).

Secondary Attack Rate

After 14 days, for all 76 households (275 household contacts) who completed follow-up of an asymptomatic SARS-CoV-2–positive child, the combined and clinical SARs were 19.6% (95% CI: 15.1%–24.8%) and 13.5% (95% CI: 9.7%–18.1%), respectively. Among the 50 exposed households where the asymptomatic SARS-CoV-2–positive child was the index case, with 179 household contacts, the combined and clinical SARs were 14.0% (95% CI: 9.2%–19.9%) and 10.6% (95% CI: 6.5%–16.1%), respectively. Among unexposed households (ie, SARS-CoV-2–negative child) with no symptomatic household contacts at baseline, the clinical SAR was 2.0% (95% CI: 1.0%–3.3%; RR exposed vs unexposed, 5.4; 95% CI: 2.7–10.7). The clinical SAR RR between exposed and unexposed households differed by household contact age group, being greatest for household contacts younger than 18 years (RR, 11.9; 95% CI: 1.3–112.5) (Table 2, Supplementary Table 4). A stratified analysis demonstrated that, when the index child had a known SARS-CoV-2–positive non-household exposure, the clinical SARs were similar for SARS-CoV-2–positive exposed and unexposed households (RR = 1.4; 95% CI: .5–3.7),

whereas when there was no known external exposure, the clinical SARs differed significantly (RR = 8.1; 95% CI: 3.2–20.5) (Supplementary Table 5).

Risk Factors for Household Transmission

The combined SAR among household contacts of SARS-CoV-2–positive pediatric index cases was higher if the index child was younger than 5 years, or 5 to younger than 13 years, compared to 13 to younger than 18 years of age (RRs = 11.1 [95% CI: 2.6–47.8] and 8.0 [95% CI: 1.9–34.5], respectively) (Figure 2, Supplementary Figures 1 and 2). Unadjusted analysis also demonstrated that the combined SAR was higher among contacts of children discharged compared with those admitted to the hospital (RR = 3.0; 95% CI: 1.1–8.2) (Supplementary Table 6), that caregiver household contacts (ie, mother, father, or equivalent) were more likely to be secondary cases compared with siblings and other children (RR = 2.7; 95% CI: 1.1–6.5), and that pre-symptomatic index cases led to higher combined SARs (42.3%; 95% CI: 23.4%–63.1%) compared with fully asymptomatic index cases (9.2%; 95% CI: 5.1%–14.9%) (Supplementary Table 7). Combined SARs also differed according to whether or not the household contacts had previous known infection or vaccination (Supplementary Table 8). In the adjusted GEE model, index case age younger than 5 years vs 13

Table 1. Baseline Characteristics of Asymptomatic Participating Children Included in Transmission Analysis (ie, Complete 14-Day Follow-up)

SARS-CoV-2 Status	All Participants		
	Positive (n = 76)	Negative (n = 198)	*P*
Demographic and clinical characteristics			
Male	45 (59.2)	112 (56.6)	.69
Country			.39
Canada	19 (25.0)	40 (20.2)	
United States	57 (75.0)	158 (79.8)	
Chronic illness (excluding asthma)[a]	18 (23.7)	35 (17.7)	.26
Psycho-behavioral	7 (9.2)	7 (3.5)	.21
Neurodevelopmental	6 (7.9)	12 (6.1)	.58
Pulmonary	2 (2.6)	2 (1.0)	.31
Cardiac	1 (1.3)	3 (1.5)	1.00
Kidney or liver	1 (1.3)	4 (2.0)	1.00
Hematologic	0	6 (3.0)	.19
Diabetes	0	2 (1.0)	1.00
Other	2 (2.6)	12 (6.1)	.36
Asthma	7 (9.2)	15 (7.6)	.66
Hospital length of stay (this visit)			.85
Discharged home immediately	47 (61.8)	124 (62.6)	
1 day	11 (14.5)	26 (13.1)	
2 days	4 (5.3)	14 (7.1)	
3+ days	8 (10.5)	14 (7.1)	
Unknown	6 (7.9)	20 (10.1)	
Number of household contacts[b] (median, IQR)	4 (4–5.5)	4 (4–5)	.67
Transmission risk or protective factors in the 14 days prior to SARS-CoV-2 test			
Had SARS-CoV-2–positive close contact	36 (47.4)	26 (13.1)	<.001
Attended daycare or school	41 (54.0)	110 (55.6)	.81
Attended a social gathering[a]			
10 to <50 persons	15 (19.7)	31 (15.7)	.42
>50 persons	5 (6.6)	18 (9.1)	.63
Used public transit[c,d]	9 (11.8)	38 (19.2)	.15
Wore a mask in public[c]	59 (77.6)	145 (73.2)	.46
Washed or disinfected hands[c,e]	66 (86.8)	159 (80.3)	.21
SARS-CoV-2 vaccine, ≥1 dose	20 (26.3)	46 (23.2)	.59

Data are n (%) unless otherwise stated.

Abbreviations: IQR, interquartile range; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

[a]Suboptions not mutually exclusive.

[b]Includes participant.

[c]"Sometimes" or "Always".

[d]Includes bus, train, taxi, and rideshare.

[e]Asked if children disinfected/washed hands upon home arrival.

to younger than 18 years, being pre-symptomatic vs never symptomatic, and being enrolled when the Delta and Omicron variants were circulating vs Alpha/other were associated with increased combined SARs (Supplementary Tables 9 and 10).

Of 111 participating asymptomatic SARS-CoV-2–positive children, 17 and 11 had viral load and VoC testing performed, respectively, thus limiting comparative analyses (Supplementary Table 11). The combined SAR was higher among Delta and Omicron time-period index cases than among Alpha/other VoC (Figure 3, Supplementary Figure 3).

Post–COVID-19 Condition

Among the 77 SARS-CoV-2–positive children who completed 90-day follow-up (Figure 1), 6 (7.8%; 95% CI: 2.9%–16.2%)

reported PCC; 5 of these children had persistent symptoms and 1 child had a newly diagnosed syndrome. This included 2 children who were younger than 5 years (7.7%; 95% CI: .9%–25.1%), 1 child aged 5 to younger than 13 years (3.4%; 95% CI, .1%–17.8%), and 3 children aged 13 to younger than 18 years (13.6%; 95% CI: 1.1%–29.2%) (Supplementary Table 12). All 6 children remained asymptomatic during acute infection (ie, the first 14 days of follow-up).

DISCUSSION

In this multicenter, case-ascertained household transmission study, 11% of household contacts, where an asymptomatic SARS-CoV-2–positive child was the index case, developed

Table 2. Symptoms, Secondary Attack Rates, and Relative Risks for Contacts in Households Without Co-Primary Cases

	All		<18 Years		18 to <50 Years		50+ Years	
Index Child's SARS-CoV-2 Status	Positive[a]	Negative[b]	Positive	Negative	Positive	Negative	Positive	Negative
No. (% within SARS-CoV-2 status group)	179 (50 HH)	663 (182 HH)	62 (34.3)	246 (37.1)	92 (51.4)	346 (52.2)	22 (12.2)	63 (9.5)
Any symptoms (clinical SAR) [95% CI]	19 (10.6) [6.5–16.1]	13 (2.0) [1.0–3.3]	3 (4.8) [1.0–13.5]	1 (0.4) [0–13.5]	15 (16.1) [9.4–25.5]	10 (2.9) [1.4–5.3]	1 (4.5) [.1–22.8]	2 (3.2) [0.4–11.0]
RR [95% CI] by HH contact age group (within SARS-CoV-2 status group)	…	…	ref	ref	3.4 [1.0–11.2]	7.1 [.9–55.2]	0.9 [.1–8.6]	7.8 [0.7–84.8]
RR [95% CI], SARS-CoV-2–positive vs –negative (within HH contact age group)	5.4 [2.7–10.7]	ref	11.9 [1.3–112.5]	ref	5.6 [2.6–12.1]	ref	1.4 [.1–15.0]	ref
Acute respiratory illness[c] (%) [95% CI]	7 (3.9) [1.6–7.9]	7 (1.1) [.4–2.2]	1 (1.6) [0–8.7]	0 [0–1.5]	5 (5.4) [1.8–12.2]	5 (1.4) [.5–3.3]	1 (4.5) [.1–22.8]	2 (3.2) [.4–11.0]
RR [95% CI] by HH contact age group (within SARS-CoV-2 status group)	…	…	ref	ref	3.4 [0.4–28.1]	7.1 [.9–55.2]	2.8 [.2–43.2]	0.5 [0–5.4]
RR [95% CI], SARS-CoV-2–positive vs –negative (within HH contact age group)	3.7 [1.3–10.4]	ref	Excluded	ref	3.8 [1.1–12.7]	ref	1.4 [.1–15.0]	ref
Any known illness[d] (combined SAR) [95% CI]	25 (14.0) [9.2–19.9]	13 (2.0) [1.0–3.3]	6 (9.7)	1 (0.4) [0–13.5]	18 (19.6) [12.0–29.1]	10 (2.9) [1.4–5.3]	1 (4.5) [.1–22.8]	2 (3.2) [.4–11.0]
RR [95% CI] by HH contact age group (within SARS-CoV-2 status group)	…	…	ref	ref	2.0 [.9–4.8]	7.1 [.9–55.2]	0.5 [.1–3.7]	7.8 [.7–84.8]
RR [95% CI], SARS-CoV-2–positive vs –negative (within HH contact age group)	7.1 [3.7–13.6]	ref	23.8 [2.9–194.1]	ref	6.8 [3.2–14.2]	ref	1.4 [.1–15.0]	ref

Data are n (%) unless otherwise stated.

Abbreviations: CI, confidence interval; HH, household; ref, reference; RR, relative risk; SAR, secondary attack rate; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

[a]Specific age missing for 3 HH contacts.

[b]Specific age missing for 8 HH contacts.

[c]At least 2 of: fever or feverishness, cough, sore throat, runny nose.

[d]Test-positive and/or any symptoms.

symptoms consistent with COVID-19 within 14 days, and 15% either developed symptoms or reported a positive SARS-CoV-2 test. Through follow-up of a comparable group of asymptomatic SARS-CoV-2 test-negative children, we determined that the risk of developing symptomatic illness within 14 days was 5 times greater among household contacts of asymptomatic SARS-CoV-2–positive children. The risk of household transmission was greater when the asymptomatic child was younger, pre-symptomatic, and tested positive during periods of Delta and Omicron circulation. After 90 days, approximately 1 in 13 SARS-CoV-2–positive, asymptomatically infected children reported PCC.

Our estimate that 15% of household contacts of an asymptomatic pediatric index case became a secondary case within 14 days is lower than that (29%) reported by a Canadian case-ascertained household transmission study of 13 asymptomatic pediatric index cases [5]. However, that study used systematic antibody testing, thereby enabling the identification of asymptomatic cases. Our estimate is also lower than reported in a Spanish study with only 36 household contacts (47%) [8]

but exceeds that reported in a German study of 20 children (2%) [7].

While some reports have concluded that symptomatic pediatric index cases contribute more to household transmission than their asymptomatic counterparts [7, 10], others have reported that the risk does not differ between these groups [5, 32]. A living systematic review concluded that household SARs from asymptomatic index cases are approximately one-third of those from symptomatic index cases [33]. As in our study, a small study from China reported that pre-symptomatic index cases were associated with increased household transmission compared with asymptomatic index cases [34].

Our finding that younger SARS-CoV-2–infected children are associated with higher household SARs has been suggested previously [6, 32, 35, 36]. Interestingly, 2 studies that looked at household transmission across pediatric and adult age groups found that young children were one of the populations that contributed most to household transmission [6, 35]. This may be due to prolonged duration of viral shedding in the very young, as previously reported for children less than 3 years
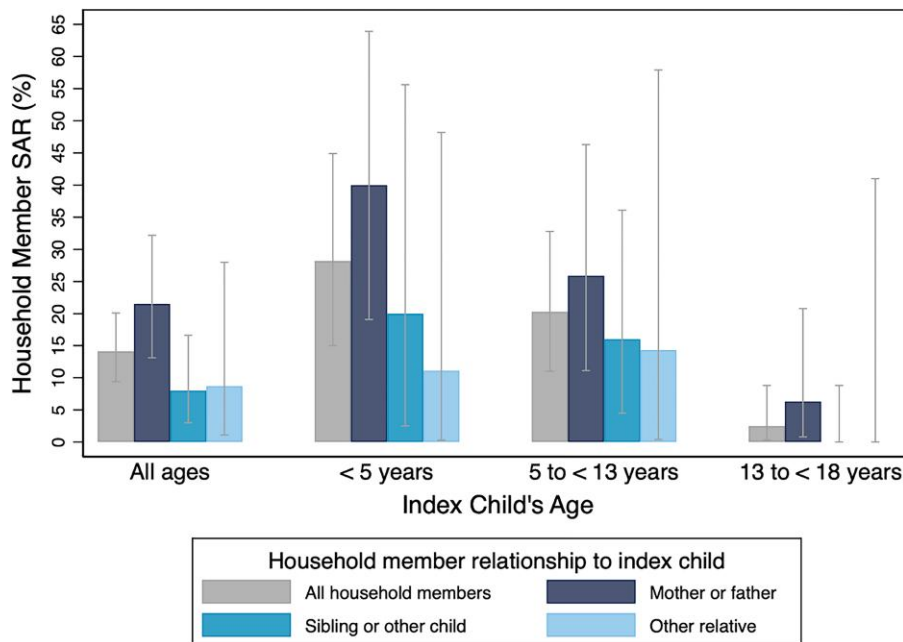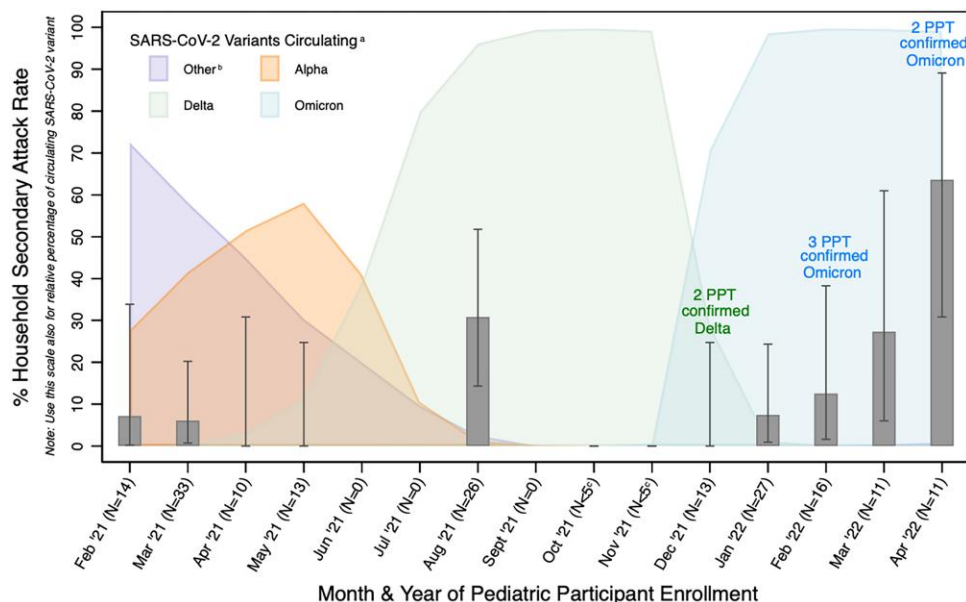
Figure 2. Household (HH) contact combined SARs (ie, test and/or symptoms after 14 days), according to the index child's age group and HH contact relationship to the index child, for 50 households (177* HH members) with a SARS-CoV-2–positive asymptomatic** index child. Fisher's exact test *P* values for HH SARs: across index child age groups = <.001; by relationship to index child = 0.043, *2 of the total 179 HH members were missing information on relationship to index child; **asymptomatic at the time of testing. Abbreviations: SAR, secondary attack rate; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

of age [9]. It may also be from closer contact due to their care needs, and a reduced ability to adhere to control measures (eg, mask wearing) among very young children. Finally, our finding of a higher SAR from asymptomatic children enrolled during periods of Delta and Omicron VoC circulation aligns with prior reports [36–38]. However, it is unclear if this finding indicates increased transmissibility of those SARS-CoV-2 variants or changes to isolation and preventive behaviors when compared with earlier pandemic time periods. In adjusted analysis, we did not find an association of household contact relationship to the index child (eg, parent vs sibling) and likelihood of becoming a secondary case, although others have found an association [5, 39]; this requires further evaluation as it has public health implications.

We observed an 8% risk of PCC 90 days after asymptomatic pediatric SARS-CoV-2 infection and the risk was greatest among adolescents, a finding previously reported in symptomatic children [19]. This estimate is comparable to another prospective cohort study, which found that 4% of 113 asymptomatic SARS-CoV-2–infected children reported PCC after 3 months [19]. Three other prospective studies reported that the PCC risk among asymptomatic children ranged from 0% to 27% [17, 18, 20]. All children reporting PCC in our study remained asymptomatic throughout the initial 14-day follow-up period; incident symptoms following the acute phase of SARS-CoV-2 illness was also observed in a prospective study of infected children in the United Kingdom [40]. Moreover, there are reports describing lung and other organ

damage in individuals who were infected but asymptomatic during the acute SARS-CoV-2 infection phase [41].

Our study, to our knowledge, is the largest published pediatric asymptomatic SARS-CoV-2 household study with active prospective follow-up, which allowed us to analyze risk factors associated with household transmission. Additionally, the inclusion of similar, but unexposed "control" households allowed us to contextualize our SAR findings, which may have otherwise been considered nonspecific to SARS-CoV-2, by enabling us to incorporate the background clinical attack rate into our analyses. However, households with a SARS-CoV-2–positive index child would have been more vigilant to report their symptoms, which may have inflated their clinical SAR. Our estimate of the combined SARs has multiple limitations: we did not systematically test household contacts for SARS-CoV-2 infection during follow-up (ie, underestimating SARs) and positive tests reported to us may have been either via antigen or NAAT. Importantly, our analytic approach implies, but does not assign with certainty, the directionality of the SAR. Furthermore, some participants were hospitalized, reducing household contact exposure and possibly the SAR. A large proportion of pediatric participants had chronic underlying illnesses, which limits the generalizability of our findings. Last, the interpretation of our findings regarding PCC in SARS-CoV-2–positive children is limited by our lack of an asymptomatic, uninfected pediatric control group with 90-day follow-up. In a similar prospective cohort study

Figure 3. Household (HH) contact combined SARs (ie, test and/or symptoms after 14 days), by time of SARS-CoV-2–positive asymptomatic index participant enrollment, with relative percentage of circulating SARS-CoV-2 variants: 179 HH contacts, 50 index participants (ie, HH). Secondary attack rate among household contacts includes either becoming symptomatic or test-positive within 14 days. [a]Using publicly available Canadian data (health-infobase.canada.ca/covid.19/testing-variants.html), which are analogous to US CDC data (covid.cdc.gov/covid-data-tracker/#variant-summary). [b]Includes gamma, eta, beta, and other variants. [c]Data from months with <5 household contacts (hence, very large confidence intervals) excluded from figure for visual purposes. Abbreviations: CDC, Centers for Disease Control and Prevention; N, number of household contacts for pediatric participants enrolled during that time; PPT, index pediatric participant; SAR, secondary attack rate; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

recruiting SARS-CoV-2–tested symptomatic and asymptomatic children, PCC-type symptoms were also reported at a relatively high frequency for SARS-CoV-2–negative children; however, this occurred among a greater proportion of SARS-CoV-2–positive participants [19].

In conclusion, we found that asymptomatic SARS-CoV-2–infected children, especially those younger than 5 years and pre-symptomatic, are important sources of transmission within households, with 11% of household contacts developing symptoms within 2 weeks. We determined that the risk of developing symptomatic illness within 14 days was 5 times greater when contacts were exposed to an asymptomatic SARS-CoV-2–positive child in their household. The fact that approximately 1 in 13 asymptomatically infected children developed PCC is concerning and requires further investigation.

Supplementary Data

Supplementary materials are available at *Clinical Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

Notes

Health Resources and Services Administration (HRSA), and Patient-Centered Outcomes Research Institute (PCORI). R. M. reports royalties or licenses for Affinivax; consulting fees from GSK, Affinivax, and Merck; payment for lectures and support for meetings and/or travel from GSK; patents planned, issued, or pending for Boston Children's Hospital; being a member of the Affinivax board of directors; and stock options for Affinivax and Corner Therapeutics. S. M. M. reports grants from Sanofi, Merck, Pfizer National Minority Quality Forum (US); support for meetings and/or travel from Sanofi, Merck, GSK, Pfizer, CSL, Biosciences Association of Manitoba (BAM), and the National Minority Quality Forum (US); and participation on a Data and Safety Monitoring Board or Advisory board for Sanofi. T. A. F. reports grants from the National Heart, Lung, and Blood Institute (NHLBI) and leadership or fiduciary roles for the Society of Pediatric Research and the Pediatric Academic Societies. All other authors report no potential conflicts. All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Conflicts that the editors consider relevant to the content of the manuscript have been disclosed.

Data availability. Deidentified data are available upon request from the principal investigator of the study (S. B. F.; Stephen.freedman@albertahealthservices.ca); however, evidence of ethics approval for use of the data will be required as well as contracts from both parties permitting data sharing. There must be a valid scientific purpose for use of the data and the request will need to be reviewed and approved by the study's leadership team.

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