Brazilian Journal of Microbiology (2022) 53:1345–1348
https://doi.org/10.1007/s42770-022-00762-w

CLINICAL MICROBIOLOGY - SHORT COMMUNICATION

Household transmission of COVID-19 according to index case: children, parents, and healthcare workers

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Received: 21 September 2021 / Accepted: 16 April 2022 / Published online: 28 April 2022

Abstract

The first SARS-CoV-2 intrafamilial transmission was investigated in China. We evaluated the dynamics of SARS-CoV-2 transmission in 242 individuals from 60 family clusters, including 30 healthcare workers (HCW) and 30 patients, in São Paulo city. Sixty index cases with COVID-19 were selected, being 30 HCW index cases from Hospital São Paulo (HSP) and its 93 household contacts and 30 index case patients from Hospital Infantil Sabará (HIS) and its 89 household contacts. Asymptomatic and symptomatic individuals participating were tested for COVID-19. The secondary attack rates in the family clusters of HCW and HIS patients were 37.63% and 68.54%, respectively. Considering all households, the transmission from adults to children was 55.4%, while the transmission from children to children was 37.5%. Children were more infected if the index case was an adult, suggesting that children were less competent to transmit. The average time for a household to be COVID-19 positive was 4 and 3 days for HCW and HIS patients. Although HCW have a higher risk of infection and social vulnerability, the secondary attack rate was lower than that observed for HIS patients, possibly because HCW are more aware of transmission risks than the general community.

Keywords COVID-19 · Household transmission · Children · Healthcare workers · SARS-CoV-2

Introduction

As of April 2022, more than half-billion cases of coronavirus disease 2019 (COVID-19), caused by the severe acute respiratory syndrome-related coronavirus 2 (SARS-CoV-2), were confirmed worldwide, with more than 6.1 million related deaths [1]. About 6% of cases and 10.6% of deaths occurred in Brazil since the first case of COVID-19 was confirmed on 26 February 2020 [2].

The first investigation of SARS-CoV-2 transmission in a family cluster in China reported a high rate (85.71%) of intra-family transmission [3].

Understanding the epidemiology of COVID-19 in children and adults is important. Children are usually the main drivers of respiratory viral outbreaks, whereas the number of COVID-19 cases is much lower in children than in adults [4, 5]. On the other hand, adults, especially healthcare workers (HCW), are at increased risk of infection due to long working hours and exposure to infected patients [6]. Thus, COVID-19 in children, adults, HCW, and the impact of familial transmission became an important issue. Studies on SARS-CoV-2 transmission within households are limited, with, to the best of our knowledge, two related studies in Brazil so far [7, 8].

In this study, we evaluated the transmission dynamics of SARS-CoV-2 in asymptomatic and symptomatic households in family clusters of HCW in a general hospital (Hospital São Paulo — HSP) and patients in a pediatric hospital (Hospital Infantil Sabará — HIS).

Responsible Editor: Fernando R. Spilki

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Material and methods

A COVID-19 index case was defined as the first SARS-CoV-2-confirmed case in a family cluster. A family cluster was characterized by having at least three individuals, including one child (under 18 years old). HCW were described as all professionals having direct and indirect contact with infected patients.

We prospectively investigated the transmission dynamics of SARS-CoV-2 in 60 family clusters from 16 April to 3 November 2020, of which 30 were from HCW working at HSP and 30 from pediatric patients attended at HIS. To determine the index case, the HSP HCW, HIS patients, and their household contacts were interviewed to obtain clinical, epidemiological, and demographic data and the potential source of infection. All households have been tested by SARS-CoV-2 real-time reverse transcription-polymerase chain reaction (RT-qPCR) using the CDC protocol [9].

We recruited HCW and patients who sought their respective healthcare services for the COVID-19 diagnostic test and were promptly confirmed positive for SARS-CoV-2 infection. All investigated pediatric patients from HIS had any comorbidity and were previously healthy. They were included only due to SARS-CoV-2 infection.

Respiratory samples were collected with nasopharyngeal swabs and stored in 2 mL of sterile lactated Ringer's solution before RNA extraction with Quick-RNA Viral Kit (Zymo Research, USA), following the manufacturer's instructions.

All participants were monitored for 14 days, and sample collection of households occurred during the first week of the index case home isolation. A new test was made 7 days later if the first result was negative.

We investigated the secondary attack rate for each family, the odds ratio (OR) of transmission for children and adult contacts, with a 95% confidence interval (CI), and the Fisher's exact test for categorical data. All analyses were performed using GraphPad Prism 6.0 (GraphPad Software, CA, USA), with $p < 0.01$ considered statistically significant.

Results

The 60 investigated family clusters comprised 242 individuals (123 from HSP and 119 from HIS). In the 30 family clusters of HIS patients, 19 adults (63.33%) and 11 children (36.66%) were identified as the index cases. In the cluster of HSP, all 30 HCW (23 female and 7 male) were the index cases.

The 30 investigated HCW were composed of eight nurse technicians, seven physicians, six administrative staff, four nursing assistants, two nurses, one physiotherapist, one psychologist, and one radiology technician. The mean age of HCW index cases was 42 years old (19 to 60 years old). The number of household contacts varied from 2 to 9. The mean age of adult households was 47 years old (18–83) and 9 years old (10 months–17 years) for children. Ninety-three households were investigated (50 adults and 43 children), of which 35 had a positive result (21 adults and 14 children), and 25.71% (9/35) were asymptomatic (5 adults and 4 children), resulting in a secondary attack rate of 37.63% (35/93). The mean age of positive adults and children was 45 years (18 to 83) and 8 years (10 months to16 years), respectively, with the number of infected households varying from 0 to 3. At least one individual was infected in 19 family clusters (63.33%) and none in eleven (36.7%). The time in days that a household of HCW took to be tested positive ranged from 1 to 9.

The 30 family clusters of HIS patients comprised 89 members (50 adults and 39 children), with a mean age of adults and children households of 40 years old (31 to 60) and 4 years old (1 month to 7 years), respectively. The number of household contacts ranged from 2 to 7. A total of 61 households were positive (31 adults and 30 children), resulting in a secondary attack of 68.54% (61/89), of which 11.47% (7/61) were asymptomatic. The time in days that a household of HIS took to be tested positive ranged from 1 to 6.

Adults, with an average age of 34 years old (ranging from 19 to 47), were the index cases in 19 family clusters from HIS, with 59 households (31 children and 28 adults) in total, and were responsible for a secondary attack rate of 71.86% (42/59), of which 64.28% (27/42) were children, and 35.71% (15/42) were adults.

Children, with an average age of a year old (ranging from 1 month to 7 years), were the index case in 11 family clusters from HIS, with 30 households (8 children and 22 adults) in total, and were responsible for a secondary attack rate of 63.33% (19/30), of which 84.21% (16/19) were adults, and 15.79% (3/19) were children.

In children, the total secondary attack rate was 53.66% (44/82), of which 61.36% (27/44), 31.82% (14/44), and 6.82% (3/44) had an adult, an HCW, and a child as the index case, respectively. In adults, the total secondary attack rate was 52.0% (52/100), of which 28.85% (15/52), 40.38% (21/52), and 30.77% (16/52), and had an adult, an HCW, and a child as the index case, respectively.

The odds of SARS-CoV-2 transmission when the index case was an adult were 13.98 and 11.25 higher when compared to HCW and children as index cases, respectively (Table 1).

Table 1 Odds ratio and proportion of the secondary attack rate of SARS-CoV-2 infection

Index case	Secondary attack rate OR (95% CI)	*p*-value*
Children		
Parental IC × Child IC	11.25 (1.91 to 66.4)	$p < 0.01$
Parental IC × IC HCW	13.98 (4.09 to 47.77)	$p < 0.001$
Child IC I × HCW IC	1.24 (0.25 to 5.95)	$p = 0.40$
Adults		
Child IC × Parental IC	2.31 (0.7 to 7.65)	$p = 0.17$
HCW IC × Child IC	0.27 (0.09 to 0.81)	$p < 0.01$
HCW IC × IC Parental	0.62 (0.24 to 1.59)	$p = 0.22$

OR, odds ratio; *CI*, confidence interval

*Significant at $p < 0.01$

Discussion

We reported the data on SARS-CoV-2 transmission in 60 family clusters from one general and one pediatric hospital. Household transmission is important, with adults being more affected [10], as observed in our study, regardless of whether the index case was adult, child, or HCW. Children did not frequently transmit to other children, and we observed that transmission occurred more from children to adults. However, the odds of children having an infection from adults were higher when compared to a child, but it should be interpreted with caution once the study was conducted when the schools were closed [11–13].

There is little evidence about the risk of SARS-CoV-2 transmission within HCW households. However, besides the frequent contact with the public, low-income professionals, in general, routinely utilize public transport during rush hours [14]. Consequently, they are at a higher risk of exposure [15], supporting the argument that the SARS-CoV-2 transmission dynamics are driven by social inequalities and vulnerabilities [16].

A systematic review of 11 studies reported that 10% of patients infected by SARS-CoV-2 were HCW [17]. In our study, the HCW occupation with the highest number of index cases was nurse technicians. In another study with HCW who had direct contact with patients, the most contaminated group was also nurse technicians, with those reporting daily patient contact having the highest infection rate [18]. We observed a SARS-CoV-2 transmission in HCW families of 37.63%, relatively lower than in HIS patients, possibly because HCW are more aware of transmission risks than the general community and had privileged access to a rapid diagnostic service.

The time after contact with the index case may be important in the dynamics of SARS-CoV-2 transmission. We observed that the average time of index case transmission was 3.4 days. In fact, during infection, the viral load reaches its peak at the beginning of the onset of symptoms, with the highest viral loads being observed in the first 5 days, indicating a high level of infectiousness and a higher risk of secondary transmission during this period [19].

Of the total 96 households infected, 16.67% (16/96) were asymptomatic. In a similar study in South Korea, with recruited participants from a community facility designated for the isolation of patients with mild symptoms of COVID-19, the asymptomatic rate of infection was 19.2% [20].

Our results have shown that family clusters will continue to be an important environment for SARS-CoV-2 transmission since individuals with suspected or confirmed infection are isolated at home.

Some points should be mentioned as limitations of the study. As the city of São Paulo went through some quarantine periods, impacting mainly the school activity suspended during the study, it may have influenced the number of children identified as index cases. We also observed that some children presented symptoms 1 or 2 days after the adult index case. It was not possible to verify whether it was a household infection in these cases. In addition, the index case groups are composed of highly selected individuals (i.e., HCW and patients from a pediatric hospital) that have very peculiar characteristics that differentiate them from the general population. For example, in two Brazilian studies in the general community, the infection rate in children varied from 22.8 to 25.1%, and both concluded that children are not significant sources of SARS-CoV-2 infection in their households and most frequently acquire the virus from adults [7, 8]. In our study, the infection rate in children was higher (55.66%), of which 61.36% had acquired COVID-19 from adults. In this sense, the results may be interpreted with caution since the activities and routines of households of HCW and pediatric patients may be distinct from non-HCW healthy people. Thus, further studies are needed to better understand the dynamics of intrafamilial transmission of SARS-CoV-2 in children and adults.

In summary, we observed that the transmission of household contacts from non-HCW patients was higher than that observed for HCW households. The SARS-CoV-2 secondary attack rate in the pediatric population was lower, suggesting that children are not the main drivers of infection but, conversely, acquire the infection more often from adults.

Acknowledgements J.M.A.C., D.D.C., L.V.L.M., A.P.C.C., and L.K.S.L. are fellows of the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, CAPES. G.R.B. is supported by the São Paulo Research Foundation, FAPESP (grant 2020/11719-0).

Author contribution Joseane M. A. Carvalho: investigation, formal analysis, writing — original draft, visualization. Clarice N. Camargo: investigation, visualization, formal analysis. Luciano K. de Souza Luna: investigation, visualization, writing — review and editing. Anna

C. Rabha: investigation. Danielle D. Conte: investigation. Roberta F. Mariano: investigation. Francisco I. O. Junior: investigation. Gabriela R. Barbosa: investigation. Luiz V. L. Moreira: investigation. Ana P. C. Chaves: investigation. Ana H. Perosa: investigation. Nancy Bellei: conceptualization, supervision, writing — review and editing.

Funding This work was supported by the Instituto de Pesquisa PENSI—Hospital Infantil Sabará, São Paulo, SP, Brazil.

Data availability Not applicable.

Code availability Not applicable.

Declarations

Ethics approval The National Research Ethics Committee approved the study with authorized written consent terms from all participants (number 29429720.1.1001.5505). Written consent terms for index cases were not applicable. The data collected were used for diagnosis purposes since index cases sought health services as suspected cases of COVID-19.

Consent to participate Not applicable.

Consent for publication Not applicable.

Conflict of interest The authors declare no competing interests.

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