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Original Articles

The role of children and adolescents in the transmission of SARS-CoV-2 virus within family clusters: A large population study from Oman



Abdullah Alqayoudhi*, Abdullah Al Manji, Sulien Al khalili, Amal Al Maani, Hanan Alkindi, Fatma Alyaqubi, Bader Al Rawahi, Amina Al-Jardani, Adil Al Wahaibi, Seif Al-Abri

Directorate General for Disease Surveillance and Control (DGDSC), Ministry of Health, Muscat 393, Oman

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ABSTRACT

Background: In Oman, many extended families tend to live in one household. Some families can include 20–30 individuals with the majority of them being children. This study investigates the role of children in spreading SARS-CoV-2 causing COVID-19 within family clusters in Oman.

Methods: This retrospective study includes data of 1026 SARS-CoV-2 positive children (≤ 18 years) collected from the national surveillance database for COVID-19 between 1 February 2020 and 30 May 2020.

Results: We included 1026 patients. Most, 842 were Omani (82%), 52% male, and 28.5% asymptomatic. Close to the half of symptomatic 419 (40%), patients presented with fever associated with other respiratory symptoms. Fifty pediatric patients were index cases who transmitted the virus to 107 patients in total (86 adults and 21 children) with a mode of 1. There is no statistical significance of all studied risk factors in the transmission of the SARS-CoV-2 virus including age, gender, and cycle threshold (CT) value.

Conclusions: According to this study, children are not to be considered a significant driver of transmission of SARS-CoV-2 in Oman.

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Introduction

SARS-CoV-2 virus was first identified to be a novel pathogen and highly contagious virus to the general population in Wuhan in December 2019 [1]. The initial cases of COVID-19 disease were imported to Oman on 24 February 2020 as travel-related disease of 2 Omani nationals who returned from a visit to Iran [2]. Due to an increasing number of cases, Oman has introduced multiple non-pharmaceutical interventions to control the spread of the disease since mid-March 2020 [3]. The interventions include stopping international travel, closing schools and shops, sending public and private-sector workers home, mandatory universal masking in public and working spaces, and restricting movement in some area with high population densities [3]. Oman registered so far 268,545 confirmed COVID-19 cases, 10,346 of whom are children (Ministry of Health, Oman, 30 of June 2021).

In April 2020, the United States reported that out of 149,760 confirmed patients, 2572 infected individuals (1.7%) were younger than 18 years old [4,5]. The proportion of infected children in different countries varies between 1.2% to 5% depending on testing and case identification strategies. Different testing practices may account, in part, for the variable proportions of pediatric cases in different countries [5].

Data from China suggest that the disease in pediatric COVID-19 patients might be less severe than adult patients and that children might experience different symptoms than adults [4]. Reports continue to indicate that children have a milder form of the disease compared to adults; however, there are reports of severe disease in children [5,6].

Person-to-person spread in children was well demonstrated early in this pandemic and contact tracing in various countries has determined that the major risk factor for acquiring COVID-19 infection in childhood is household exposure [5,7]. In one US report of 184 children, 168 (91%) had been exposed to COVID-19 in a home setting [4,5].

There is limited evidence detailing the direct transmission of COVID-19 from children [8]. A case series from China described

* Corresponding author.

E-mail address: alqaudi99@gmail.com (A. Alqayoudhi).

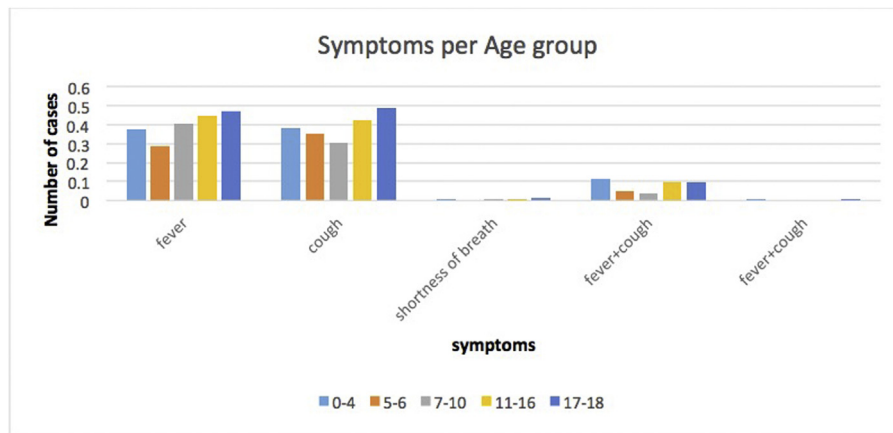


Fig. 1. Symptoms of COVID-19 in pediatrics by age group, Oman, February–May 2020.

the direct transmission of SARS-2 to the parents who developed symptoms 7 days after looking after an infected infant [8,9].

This study investigates the role of children in spreading SARS-CoV-2 virus within family cluster outbreaks and to figure out the risk factors of transmission of SARS-CoV-2 virus among children in Oman.

Methods

This is a retrospective cross-sectional national study that included children less than 18 years old who were confirmed with COVID-19 based on positive SARS-CoV-2 between 1 February 2020 to 30 May 2020. The data was obtained from the national COVID-19 surveillance system (Trussad+), Ministry of Health, Oman. The data included the geographic area, age, and gender, clinical manifestation (fever, cough, difficulty in breathing, headache, and diarrhea). The epidemiological data such as classification into index cases or contact were also included. During the study period, there were 4 patients with mild symptoms and one with severe lower respiratory infection, all of whom required admission to the hospital those were excluded from this study as the scope of this study to focus on non-admitted patients [10].

Statistical analysis

Descriptive analysis was performed by using mean ± SD for continuous data, frequency, and proportion for categorical data. Associations were investigated using chi-square analysis, statistical significance was determined at p-value <0.05. Data analysis was done using MS Excel (Microsoft, Redmond, WA, USA) and Epi Info version 7(Tony Burton, Geneva, Switzerland).

Laboratory method

Respiratory specimens collected from suspected cases as per the Ministry of Health national case definition were used in this study.

RNA extraction of samples was carried out through MagMax™ Viral Pathogen Extraction Kit (Thermo Fisher Scientific, Waltham, MA, USA) or Viral RNA Isolation Kit with Liferiver EX3600 (Liferiver Bio-Tech, Hangzhou Bay, China), following manufacturer protocol. For the detection of the SARS-CoV-2 virus by real-time polymerase chain reaction (RT-PCR) system, Novel Coronavirus (2019-nCoV) Nucleic Acid Diagnostic Kit, CE-IVD, FDA-EUA (Sansure Bio-Tech, Changsha, China) was used according to manufacturer instructions. The assay targets 2 genomic regions of the SARS-CoV-2 (N and ORF1ab), or using Liferiver Novel Coronavirus (2019-nCoV) Real-

Table 1

Pediatric COVID-19 cases and percentages by age group, Oman, February–May 2020.

Age group	Symptomatic		Total
	Yes	No	
0–4	210(20%)	116(11%)	326(31%)
5–6	48(4.6%)	29(2.8%)	77(7.5%)
7–10	146(14%)	55(5%)	201(19.5%)
11–16	224(21%)	65(6%)	289(28%)
17–18	105(10%)	28(2.7%)	133(12.9%)
Grand total	733(71.4%)	293(28.5%)	1026

Time Multiplex RT-PCR Kit which targets 3 genes ORF1ab, E, N (Liferiver Bio-Tech, Shanghai, China).

Eighty-seven randomly selected samples out of the total sample size of the study were tested for the correlations between SARS-CoV-2 CT values and patient’s epidemiological characteristics to determine the association between the two, where low CT values indicate high viral load. CT values were extracted from the laboratory records in which each sample labeled by a unique code number whereby CT values expressed using targeted genes: envelope (E) protein, nucleocapsid protein N and the open reading frame 1 (ORF1) ab, according to the national standard operation procedure of testing, reporting and interpreting the SARS-CoV-2 positive PCR tests. The test with a CT value of ≥40 was considered negative.

Results

During the study period, 1026 pediatric patients were identified. The majority of the study population are Omani (842). 52% of them were male and 48% were female. This study included all non-admitted pediatric patients from all governorates of Oman (Muscat, Musandam, Alburimi, North Batinah, South Batinah, Dakhliya, South Sharqya, North sharqyah and Aldahirah), more than half of the patients (609) were from Muscat governorate, the capital of Oman and no contributors were from Musandam and Alburimi governorates. Out of 1026 patients, 326 were from 0 to 4 years old, 77 from age group 5 to 6, 201 from 7 to 10, 289 from 11 to 16, and 133 from age group 17 to 18 (Fig. 1). Around 293 were asymptomatic, 116 from the 0 to 4-year-old age group. Table 1 shows 419 patients presented to health care institutes with fever associated with other respiratory symptoms whereas 111 patients complained of fever alone. Four hundred patients presented with cough associated with other respiratory symptoms, 71 coughs with fever and 72 patients had cough alone. Fever and cough were the most predominant symptoms among older age groups with p-value of 0.02 and 0.008, respectively (Fig. 2).

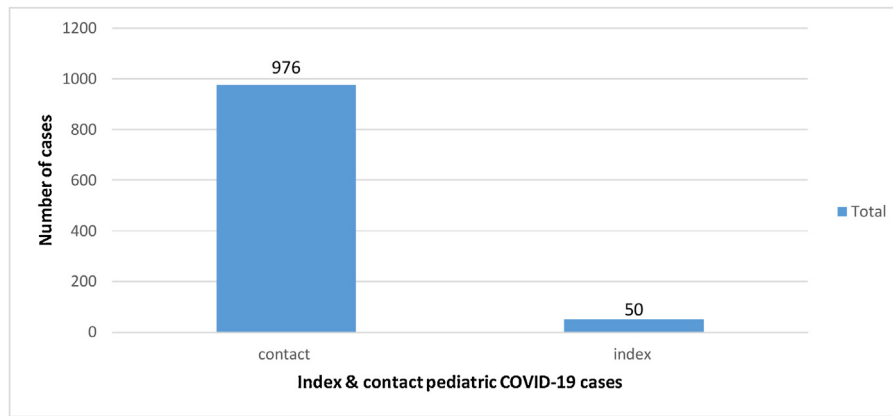


Fig. 2. Index and contact pediatric COVID-19 cases, Oman February–May 2020.

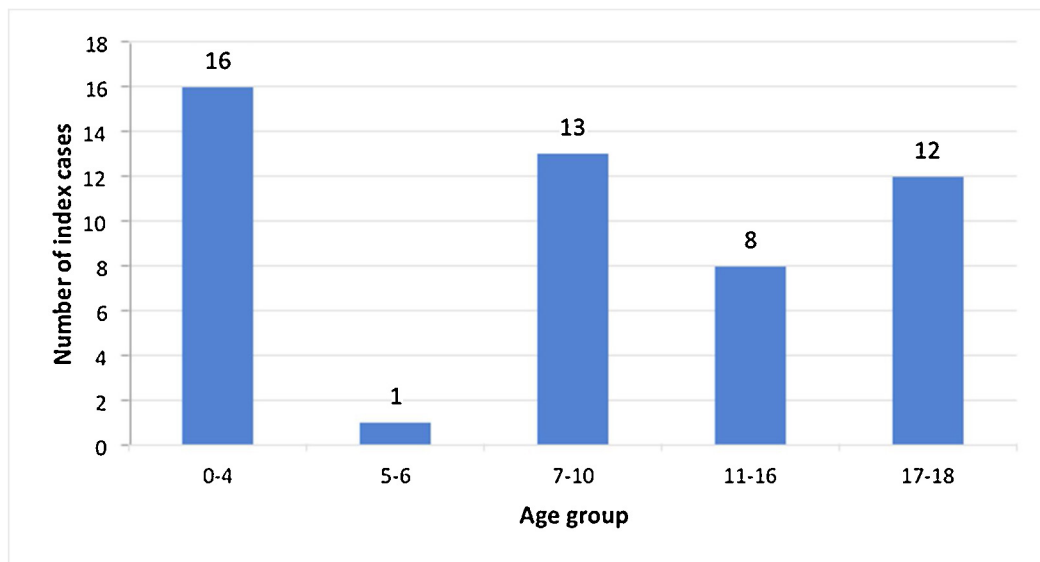


Fig. 3. Index pediatric cases of COVID-19 by age group, Oman, February–May 2020.

Out of 1026 patients, 50 patients were index cases, which is important to recognize early in order to prevent the spread of the disease by conducting contact tracing and isolation. Across age groups, it broke down as follows, 16 (30%) patients from age group 0–4 were index cases, one (2%) was from 5 to 6, no index patients came from the age group 7 to 10, 8 (16%) were from 11 to 16, and 12 (24%) were from ages 17 to 18 (Fig. 3). There were 107 secondary cases due to contact with index cases, 21 patients were less than 18 years, and 86 patients were adults (Table 2).

Regarding the mean CT values, there was no significant association in CT values between whether the individual is COVID-19 index or contact case ($p = 0.4189$), and no statistically significant variation among age groups ($p = 0.1841$).

Discussion

The study was conducted during the first stage of the pandemic where most social activities were banned. It is also obvious that most of the patients were from Muscat governorate, which is the capital of Oman, and has a higher population density than other governorates.

In our study, we found 29% of patients had no symptoms and they were tested because of active contact tracing during family outbreak. The majority of them were less than 4 years old. Interest-

Table 2

Contacts (secondary cases) of COVID-19 by age group, Oman, February–May 2020.

Age group	Secondary cases
Below 18 years	21
Above 18 years	86
Total	107

ingly, none of them were associated with secondary transmission to other patients. Wuhan Center conducted a study recently for Disease Control and Prevention, using more large data found that an asymptomatic patient is less likely to transmit the disease compared to a symptomatic and presymptomatic one [11]. Another study from Greece assessed 23 family clusters, concluded that children were less likely to be the source of family outbreak and significantly more likely to have an asymptomatic infection or a mild disease [12]. In Oman, during the study period, there was a lockdown, and no children left their households, but there were social gatherings within the families.

Out of 1027 patients, there were 50 index cases who were able to transmit the infection to another one patient with a ratio of 1:1. Most secondary cases were adults, and this could be explained by strict lock down at an early stage of the pandemic and by lack of social gathering and children interaction with other children. Two exceptional index cases were able to transmit the SARS-2 virus

to more than two people. These were attributed to extended and large family gatherings during the two outbreaks. Many of the disease clusters in the Omani population are present because Omanis tend to live in extended families (5–12 per household), thereby increasing the possible number of contacts for each primary case [3].

Interestingly, around 30% of index cases were younger children less than 4 years old who were able to transmit the virus to others. Similar finding was observed in a recent population-based cohort study done in Ontario, Canada suggesting that younger age children maybe more likely to transmit the disease in comparison to the older age children [13]. Environmental contaminants with saliva and feces from infected patients with COVID-19 pose a source of indirect transmission from children to adults [8,1]. Children show prolonged virus shedding in feces compared to adults and in some cases longer than 4 weeks [14–17]. These findings lead to concerns about the potential for fecal-oral transmission of SARS-CoV-2, particularly in infants and children who are not toilet-trained and who have poorer hand hygiene [8].

Contrary to what was revealed in JAMA Pediatrics that young children had significantly lower median (interquartile range) CT values (6.5 [4.8–12.0]), indicating that young children have equivalent or more viral nucleic acid in their upper respiratory tract compared with older children and adults [18] our study showed that there is no variation among the pediatric age groups, a similar finding has been highlighted by a study from Bahrain [19]. Maltezou and her colleagues from Greece found that high viral load could be used as indicator for the severity of the disease and a marker for infectivity in children [20]. In contrast, in our study, we were unable to establish the role played by the CT values in infectiousness or disease transmission pattern as there was no association between CT values and whether the individual is a COVID-19 index or contact case. Correlation with observational epidemiological data analyzing known infector–infectee pairs is required to fully understand the dynamics of infectiousness and viral transmissibility [21,22].

A recent study of a median sample of 928,000 English school children reported that very few outbreaks were caused from children in school. School-related exposures of SARS-CoV-2 post 2020 pandemic lockdown in England were more frequently associated with staff, not students [23]. In Oman, where schools remain closed, this has not yet been studied, so we do not know if reopening of schools and colleges will change the role of children in the transmission of COVID-19.

While this study includes a large number of cases as well as utilizing a comprehensive surveillance data limitations of the study include first, the study period which was occurred during the lockdown when there was limited social interaction. Second, the major limitation for the estimation of the infectivity by the mean of CT values evaluation was the small sample size of which CT values was investigated. Third is the fact that all the patients have mild to moderate disease with no admissions. Fourth the absence of the date of onset of the symptoms as the date of testing was used instead.

In conclusion this study showed small percentage of children can transmit the COVID-19 virus to others, but no specific risk factor was found to increase risk of transmission from infected child including the CT value of positive PCR sample. A follow-up study with reopening of schools and easing lockdown measures will further add to the understanding of children's role in transmission of SARS-CoV-2 infection in large family settings.

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Conflict of interest

We have no conflict of interest.

Ethical approval

Not required

References

- [1] Wu Q, Xing Y, Shi L, Li W, Gao Y, Pan S, et al. Coinfection and other clinical characteristics of COVID-19 in children. *Pediatrics* 2020;146(1):e20200961, <http://dx.doi.org/10.1542/peds.2020-0961>.
- [2] Al-Mahruqi S, Al-Wahaibi A, Khan AL, Al-Jardani A, Asaf S, Alkindi H, et al. Molecular epidemiology of COVID-19 in Oman: a molecular and surveillance study for the early transmission of COVID-19 in the country [published online ahead of print, 2021 Jan 13]. *Int J Infect Dis* 2021;104:139–49, <http://dx.doi.org/10.1016/j.ijid.2020.12.049>.
- [3] Al Wahaibi A, Al Manji A, Al Maani A, Al Rawahi B, Al Harthy K, Alyaquobi F, et al. COVID-19 epidemic monitoring after non-pharmaceutical interventions: the use of time-varying reproduction number in a country with a large migrant population. *Int J Infect Dis* 2020;99:466–72, <http://dx.doi.org/10.1016/j.ijid.2020.08.039>.
- [4] CDC COVID-19 Response Team. Coronavirus disease 2019 in children—United States, February 12–April 2, 2020. *MMWR Morb Mortal Wkly Rep* 2020;69(14):422–6, <http://dx.doi.org/10.15585/mmwr.mm6914e4>.
- [5] Current epidemiology and guidance for COVID-19 caused by SARS-CoV-2 virus, in children: March 2020. Available online: www.cps.ca/en/documents/position/current-epidemiology-and-guidance-for-covid-19-march-2020 [Accessed 10 July 2020].
- [6] Ludvigsson JF. Systematic review of COVID-19 in children shows milder cases and a better prognosis than adults. *Acta Paediatr* 2020;109(6):1088–95, <http://dx.doi.org/10.1111/apa.15270>.
- [7] New Zealand Ministry of Health. COVID-19—Current Cases: Information about confirmed and probable cases of COVID-19 in New Zealand. Available online: www.health.govt.nz/our-work/diseases-and-conditions/covid-19-novel-coronavirus/covid-19-current-situation/covid-19-current-cases [Accessed 20 August 2020].
- [8] Li X, Xu W, Dozier M, He Yazhou, Kirolos A, Theodoratou E, et al. The role of children in transmission of SARS-CoV-2: a rapid review. *J Glob Health* 2020;10(1):011101, <http://dx.doi.org/10.7189/jogh.10.011101>.
- [9] Jiehao C, Jin X, Daojiang L, Zhi Y, Lei X, Zhenghai Q, et al. A case series of children with 2019 novel coronavirus infection: clinical and epidemiological features. *Clin Infect Dis* 2020;71(6):1547–51, <http://dx.doi.org/10.1093/cid/ciaa198>.
- [10] Al Yazidi LS, Al Hinai Z, Al Waili B, Al Hashami H, Al Reesi M, Al Othmani F, et al. Epidemiology, characteristics and outcome of children hospitalized with COVID-19 in Oman: a multicenter cohort study. *Int J Infect Dis* 2021;104:655–60, <http://dx.doi.org/10.1016/j.ijid.2021.01.036>.
- [11] Li F, Li YY, Liu MJ, Fang LQ, Dean NE, Wong GWK, et al. Household transmission of SARS-CoV-2 and risk factors for susceptibility and infectivity in Wuhan: a retrospective observational study. *Lancet Infect Dis* 2021, [http://dx.doi.org/10.1016/S1473-3099\(20\)30981-6](http://dx.doi.org/10.1016/S1473-3099(20)30981-6). S1473–3099(20)30981–30986.
- [12] Maltezou HC, Vorou R, Papadima K, Kosyvakis A, Spanakis N, Gioula G, et al. Transmission dynamics of SARS-CoV-2 within families with children in Greece: a study of 23 clusters. *J Med Virol* 2021;93(3):1414–20, <http://dx.doi.org/10.1002/jmv.26394>.
- [13] Paul LA, Daneman N, Schwartz KL, Science Michelle, Brown Kevin A, Whelan Michael, et al. Association of age and pediatric household transmission of SARS-CoV-2 infection. *JAMA Pediatr* 2021, <http://dx.doi.org/10.1001/jamapediatrics.2021.2770>. Published online August 16.
- [14] Yung CF, Kam KQ, Wong MSY, Maiwald M, Tan YK, Tan BH, et al. Environment and personal protective equipment tests for SARS-CoV-2 in the isolation room of an infant with infection. *Ann Intern Med* 2020;173(3):240–2, <http://dx.doi.org/10.7326/M20-0942>.
- [15] Xu Y, Li X, Zhu B, Liang H, Fang C, Gong Y, et al. Characteristics of pediatric SARS-CoV-2 infection and potential evidence for persistent fecal viral shedding. *Nat Med* 2020;26(4):502–5, <http://dx.doi.org/10.1038/s41591-020-0817-4>.
- [16] Ma X, Su L, Zhang Y, Zhang X, Gai Z, Zhang Z. Do children need a longer time to shed SARS-CoV-2 in stool than adults? *J Microbiol Immunol Infect* 2020;53(3):373–6, <http://dx.doi.org/10.1016/j.jmii.2020.03.010>.
- [17] Xing YH, Ni W, Wu Q, Li WJ, Li GJ, Wang WD, et al. Prolonged viral shedding in feces of pediatric patients with coronavirus disease 2019. *J Microbiol Immunol Infect* 2020;53(3):473–80, <http://dx.doi.org/10.1016/j.jmii.2020.03.021>.
- [18] Heald-Sargent T, Muller WJ, Zheng X, Rippe J, Patel AB, Kocielek LK. Age-related differences in nasopharyngeal severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) levels in patients with mild to moderate coronavirus disease 2019 (COVID-19). *JAMA Pediatr* 2020;174(9):902–3, <http://dx.doi.org/10.1001/jamapediatrics.2020.3651>.
- [19] Abdulrahman Abdulkarim, Mallah Saad I, Alawadhi Abdulla, Perna Simone, Janahi Essam M, AlQahtani Manaf M. Association between RT-PCR Ct values and COVID-19 new daily cases: a multicenter cross-sectional study. *Med Rxiv* 2020, <http://dx.doi.org/10.1101/2020.12.07.20245233>.

- [20] Maltezou HC, Raftopoulos V, Vorou R, Papadima K, Mellou K, Spanakis N, et al. Association between upper respiratory tract viral load, comorbidities, disease severity, and outcome of patients with SARS-CoV-2 infection. *J Infect Dis* 2021;223(7):1132–8, <http://dx.doi.org/10.1093/infdis/jiaa804>.
- [21] Singanayagam A, Patel M, Charlett A, Lopez Bernal J, Saliba V, Ellis J, et al. Duration of infectiousness and correlation with RT-PCR cycle threshold values in cases of COVID-19, England, January to May 2020. *Euro Surveill* 2020;25(32):2001483, <http://dx.doi.org/10.2807/1560-7917.ES.2020.25.32.2001483>.
- [22] Understanding cycle threshold (Ct) in SARS-CoV-2 RT-PCR. A guide for health protection teams. Available online: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/926410/Understanding_Cycle_Threshold_Ct_in_SARS-CoV-2_RT-PCR.pdf [Accessed 10 December 2021].
- [23] Ismail SA, Saliba V, Lopez Bernal J, Ramsay ME, Ladhani SN. SARS-CoV-2 infection and transmission in educational settings: a prospective, cross-sectional analysis of infection clusters and outbreaks in England. *Lancet Infect Dis* 2021;21(3):344–53, [http://dx.doi.org/10.1016/S1473-3099\(20\)30882-3](http://dx.doi.org/10.1016/S1473-3099(20)30882-3).