Coronavirus Disease 2019 Cluster Originating in a Primary School Teachers' Room in Japan

Yuta Aizawa, MD, PhD, Yugo Shobugawa, MD, PhD,† Nobuko Tomiyama,‡ Hitoshi Nakayama MD, PhD,‡ Masako Takahashi,‡ Junko Yanagiya,‡ Noriko Kaji,§ Tatsuki Ikuse, MD,* Ryohei Izumita, MD, PhD,*¶ Takayuki Yamanaka, MD,¶ Satoshi Hasegawa, MD, PhD,‖ Tsutomu Tamura, PhD,** Reiko Saito, MD, PhD,†† and Akihiko Saitoh, MD, PhD**

Background: School closures are a subject of debate during the present coronavirus disease 2019 (COVID-19) pandemic. Because children are not the main driver of COVID-19 transmission in the community, school education must be prioritized in conjunction with appropriate infection prevention and control measures, as determined by local COVID-19 incidence.

Methods: We investigated the causes and transmission routes of a primary school cluster of COVID-19 that occurred during November and December 2020 in Niigata, Japan.

Results: In the cluster, the virus spread among teachers, then from teachers to students, and then to their family members. This primary school cluster comprised 26 infected patients and included teachers (13/33, 39%), students (9/211, 4%), and family members (4/65, 6%). The secondary attack rate from the 3 index teachers to the remaining 30 teachers was 33%; however, the rate to students was only 4%. Factors contributing to cluster formation include the fact that 2 of the index teachers continued working while symptomatic and that the environment and infection prevention measures in the teachers' room were inadequate.

Conclusions: To open schools safely and without interruption, adequate measures to prevent COVID-19 infection in schools should be emphasized not only for children but also for teachers and their environment.

Key Words: school, cluster, COVID-19, teachers' room, child

(*Pediatr Infect Dis J* 2021;40:e418–e423)

In response to the pandemic of coronavirus disease 2019 (COVID-19), school closures were implemented worldwide in early 2020.[1] This intervention was derived from measures to reduce peak infection rates in the community during outbreaks of seasonal influenza, for which attack rates are higher in children than in adults.[2] Accumulating evidence suggests that the harms of school closures for COVID-19 outweigh their benefits.[1] School closures deprive children of their education and well-being.[3] In Japan, primary and junior high schools closed nationwide from March 2 to the end of March (before spring break) and from April 23, 2020 to the end of May 2020. The closure continued until July in large cities where case numbers continued to be high. Thereafter, primary and junior high schools have remained open, with intermittent closures when suspected or confirmed COVID-19 cases were identified in schools.

Children are not the main driver of COVID-19 community transmission.[4] Schools reopened with a variable process that was not directly correlated with the number of COVID-19 deaths.[1] School reopening had less effect than community-based nonpharmaceutical interventions on the number of COVID-19 patients.[5] School attendance was not associated with COVID-19 incidence, although close contact with COVID-19 patients (family members rather than classmates) and inconsistent use of face masks at school were risk factors among children in the US.[6] In the United Kingdom, COVID-19 outbreaks at school were correlated with regional incidence.[7] Similarly, most COVID-19 cases in Canadian schools resulted from community transmission, not from transmission within schools.[5] Even when a child was infected, school transmission was reported to be rare in developed countries such as the US,[8] France,[9] Australia[10] and Japan.[11]

The World Health Organization and other authorities have published several documents addressing key points for COVID-19 prevention and control in schools.[12] In Japan, the government published a manual of COVID-19 infection prevention and control at school.[11] The principles outlined in these documents are similar. They emphasize hand hygiene, respiratory etiquette, mask use, physical distancing, environmental cleaning, ventilation, absence of sick persons and contact tracing in combination with isolation and quarantine. Most importantly, they highlight the need for continuing education by means of measures that are consistent with levels of community transmission of severe acute respiratory syndrome-coronavirus-2 (SARS-CoV-2).

Several studies have examined COVID-19 transmission and cluster formation at school.[7,8,10,13] However, these studies address the overall characteristics of COVID-19 incidence at schools in a country; few include detailed individual descriptions. Developing evidence-based COVID-19 recommendations for schools are necessary.[14] In this report, we describe a primary school cluster of COVID-19 that originated in a teachers' room, a setting that has seldom been discussed in previous studies or guidance for COVID-19 prevention and control in schools, although the need for infection prevention among teachers was clearly demonstrated by the high secondary attack rate from a previous teacher index case.[15] In Japan, each teacher has their own desk in teachers' rooms, for work or rest, and the teachers' room facilitates easy communication

Accepted for publication July 19, 2021

From the *Department of Pediatrics, Niigata University Graduate School of Medical and Dental Sciences, Niigata, Japan; †Department of Active Aging, Niigata University Graduate School of Medical and Dental Sciences, Niigata, Japan; ‡Department of Health and Welfare, Niigata Prefectural Office, Niigata, Japan; §Kashiwazaki Health Care Center, Niigata, Japan; ¶ Department of Pediatrics, Niigata City General Hospital, Niigata, Japan; ‖Pediatric liaison, Niigata Prefectural Patient Control Center, Niigata, Japan; **Department of Virology, Niigata Prefectural Institute of Public Health and Environmental Science, Niigata, Japan; and ††Department of International Health (Public Health), Niigata University Graduate School of Medical and Dental Sciences, Niigata, Japan

This work was supported by the Health and Labour Sciences Research Grants (20CA2035).

The authors have no conflicts of interest to disclose.

Address for correspondence: Akihiko Saitoh, MD, PhD, Department of Pediatrics, Niigata University Graduate School of Medical and Dental Sciences, 1-757 Asahimachi-dori, Chuo-ku, Niigata 951-8510, Japan. E-mail: asaitoh@med.niigata-u.ac.jp

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's website (www.pidj.com)

ISSN: 0891-3668/21/4011-e418

DOI: 10.1097/INF.0000000000003292

among teachers. To better understand how to keep schools open safely and continuously, we analyzed the present school cluster originating in a teachers' room.

METHODS

Data Collection

Niigata Prefecture, Japan, had a general population of 2,199,746 in October 2020, including a population of 267,235 (12%) younger than 15 years of age.[16] There were 450 primary schools, with 105,818 students and 10,544 teachers.[17] A primary school cluster of COVID-19 occurring in Niigata Prefecture during the period from the end of November until the beginning of December 2020 was investigated by the public health service of health centers, under the authority of the Department of Health and Welfare, Niigata Prefectural Office, and officially reported by the Department.

In Japan, health centers are responsible for promoting public health in several municipalities, and for investigating outbreaks and contact tracing. We did a further investigation using the information from the health centers, which include demographic characteristics and information on the time course of symptoms and laboratory test results of patients and contact tracing, demographic data of teachers, maps and layouts of the teachers' room and classroom where COVID-19 transmission was confirmed and progression of the school cluster.

We used a database of COVID-19 incidence by prefecture in Japan for the cumulative number of patients in Niigata Prefecture.[18]

Case Definitions

The index case was defined as the first infected person, as determined by laboratory diagnosis for COVID-19 and the earliest date of symptom onset. The index case group was defined as the initially recognized patients with preceding symptoms. The secondary attack rate was defined as the percentage of persons with a laboratory diagnosis of COVID-19 among all contacts surveyed in the outbreak investigation.

Viral Analyses

A reverse transcription-PCR (RT-PCR) assay for SARS-CoV-2[19] using saliva or a nasopharyngeal swab was performed at the Niigata Prefectural Institute of Public Health and Environmental Sciences or, in a few cases, at each hospital. Rapid antigen testing was performed at each hospital for symptomatic patients. Whole-genome sequencing of positive RT-PCR samples from each teacher, student and family member was performed at the National Institute of Infectious Diseases in Japan. The virus was classified by Pango Lineage (Ver: 2021.6.5).[20] A phylogenetic tree was constructed based on whole-genome sequence with virus strains obtained in Niigata Prefecture between November 1 and December 31, 2020, using MEGA7 software.[21]

Ethics Approval

We used anonymous and public data; thus, the requirement for informed consent was waived for this study. This study was approved by the Ethics Committee of Niigata University (2020-0499).

Statistical Analysis

The proportion of symptomatic patients was compared between adults and children by using the χ^2 test and STATA version 16.1 (Stata Corp, TX, USA). A two-tailed P value of <0.05 was considered to indicate statistical significance.

RESULTS

COVID-19 Cumulative Numbers in Niigata Prefecture

The cumulative numbers of COVID-19 patients per million of the general population in Niigata were 82.8 and 151.1 on November 1, and December 1, 2020, respectively.

A COVID-19 Cluster at School

The primary school had 33 teachers and 211 students (see Table, Supplemental Digital Content 1, http://links.lww.com/INF/E542). The students were wearing masks all the time at school. The entrance doors, windows at the corridor side of the classroom and facing to outside left open, although the windows of the classroom facing to outside were closed (see Figures, Supplemental Digital Content 2, http://links.lww.com/INF/E543 and 3, http://links.lww.com/INF/E543) because of cold temperature. An air conditioner and forced flue heater were installed in every room. The students sat at their desks arranged not to face each other during classes and lunchtime. On Friday, November 20, 2020, 5 teachers (T1–T5), who were symptomatic on the day of laboratory diagnosis, were diagnosed as having COVID-19 (Fig. 1), which triggered an outbreak investigation and contact tracing. Three (T1–T3) were symptomatic before the diagnosis (T1: the index case and T1–T3: the index case group); T3 had fever, and T1 and T2 had been working with symptoms until their diagnosis. T1 developed sore throat on November 9, 2020, and later cough and fever. However, 5 days before the laboratory diagnosis, T1 was absent from school for 1 day and left early for 2 days because of symptoms. T2 worked at school with a sore throat and hoarseness during the 3 days before laboratory diagnosis. All infected teachers (T1–T5) reported no close contact with confirmed COVID-19 cases.

This school cluster included 26 patients: 13 teachers, 9 students and 4 family members. The time course and epidemic curve of the patients are shown (Figs. 1 and 2). The school closed on Tuesday, November 24, in response to the identification of multiple COVID-19 patients during the weekend and subsequent public holiday. The outbreak investigation and contact tracing included 332 individuals: all 30 teachers, 211 students, the close contacts of 65 family members and 27 others. The proportions of patients were 39% (13/33) of teachers, including the index case group, 4% (9/211) of students, 6% (4/65) of family members and 0% (0/27) of other contacts. The secondary attack rate among teachers was 33% (10/30).

The characteristics of patients are summarized in Table 1. Overall, 58% were symptomatic. The proportion of symptomatic patients was higher in adults (73%) than in children (44%), but the difference was not significant ($P = 0.16$). All patients with COVID-19 were admitted to the hospital, except for 3 students who recovered at home; thereafter, 3 teachers and 3 students were moved from the hospital to a hotel for recuperation. There were no deaths. No further infections among students were identified after school closure.

The virus was classified as genetic lineage B.1.1.214 and did not possess the representative spike mutations (eg, N501Y or E484K). The virus strains obtained from each teacher, student and family member in this school cluster made one group independent of other virus strains obtained in Niigata Prefecture in the lineage B.1.1.214 (see Figure, Supplemental Digital Content 4, http://links.lww.com/INF/E543).

A possible transmission route was identified after examining daily contacts, symptom onset and timing of laboratory diagnosis (Fig. 3). The cluster seemed to have started from the teachers, most likely T1 working while symptomatic. The 9 students with

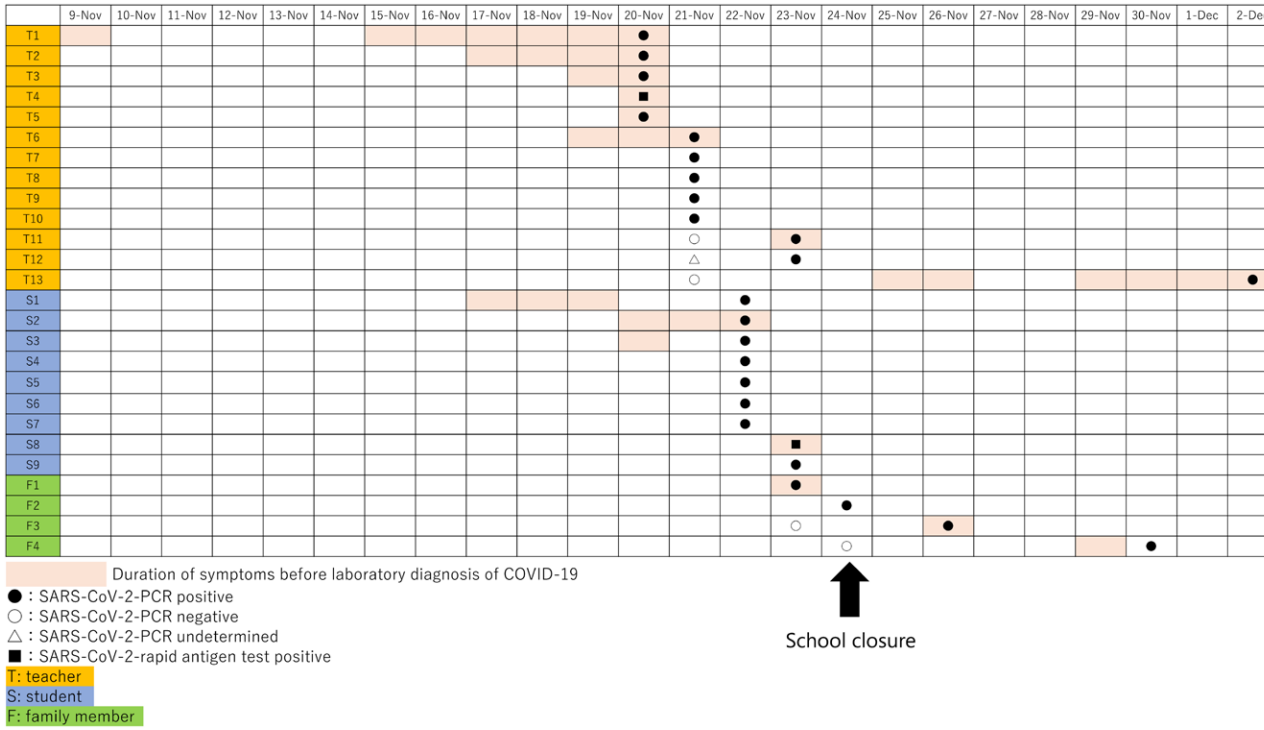

FIGURE 1. Time course of symptoms and laboratory diagnosis of patients with coronavirus disease 2019 in a school cluster during November and December 2020 in Niigata, Japan. SARS-CoV-2 indicates severe acute respiratory syndrome coronavirus 2.

COVID-19 were limited to 2 classes in the third and sixth grades. The proportion of patients was 33% in 1 third grade class and 15% in 1 sixth grade class (see Figures, Supplemental Digital Content 2, http://links.lww.com/INF/E543 and 3; http://links.lww.com/INF/E543). In total, 6 homeroom teachers (T1, T2, T4, T8, T10 and T12) were infected with SARS-CoV-2. The attack rate from infected teachers to students was low (4%). Two teachers (T5 and T7) provided special support for student S7, who had autism spectrum disorder, and student S6, who had attention deficit hyperactivity disorder (ADHD). Additionally, S5 had ADHD and S9 had a developmental disorder. In total, 44% of students requiring special educational support developed COVID-19. SARS-CoV-2 initially spread among the teachers. It then spread from teachers to students, most likely by close contact during individual instruction, and then to family members.

The Teachers' Room as a Potential Source of the Cluster

Because the teachers seemed to be the starting point of the school cluster, the teachers' room was further investigated (see Figure, Supplemental Digital Content 5, http://links.lww.com/INF/E544). The median age of the 33 teachers was 47 years (range, 24–67 years); 33% were male. The teachers' room comprised the principal's room, printing room and main room. The teachers' room at this school was reported to be the smallest in the city, and teachers found it difficult to pass behind the desks. There were no partitions between desks. Opposed to strict infection prevention and control activities in the classrooms, teachers did not always wear masks in the inadequately ventilated teachers' room (eg, the entrance doors and windows at the corridor side left always open, although the windows facing to outside were open occasionally). At lunchtime, homeroom teachers ate lunch in their own classrooms, but the other 16 teachers, who did not have their own classes, ate lunch in the teachers' room. As shown in Figure, Supplemental Digital Content 5, http://links.lww.com/INF/E544, the infected teachers were not located in a single area of the teachers' room. No specific gathering of teachers was noted between November 9 and November 20, 2020. The principal had regular contact with the teachers, to provide guidance. Teachers supporting students with special needs performed their educational activities in the teachers' room and in classrooms. Before the reopening of the school, on December 7, 2020, an extra teachers' room was established, partitions were placed between desks, and frequent air ventilation was enforced to address deficiencies in the teachers' room.

DISCUSSION

This primary school cluster likely started in the teachers' room, which underscores the importance of infection prevention and control among teachers when attempting to protect students from COVID-19 and keep schools open. At schools, teachers were the main source of COVID-19 clusters,[7] and the secondary attack rate was higher for teacher index cases than for student index cases.[15] In the household setting, most index cases are adults; children are rare drivers of COVID-19 family clusters.[22] In Japan, adults were the primary case-patients in more than 96% of familial clusters of COVID-19,[23] and this finding appears applicable to educational settings.

Among educational institutions in the United Kingdom, the risk of COVID-19 outbreaks is highest for primary schools, although rates have been very low and the size of COVID-19 outbreaks has been small. The median number of secondary cases was 1 (interquartile range 1–4) in 27 primary school outbreaks during the early summer of 2020.[7] In Japan, there were 1996 COVID-19

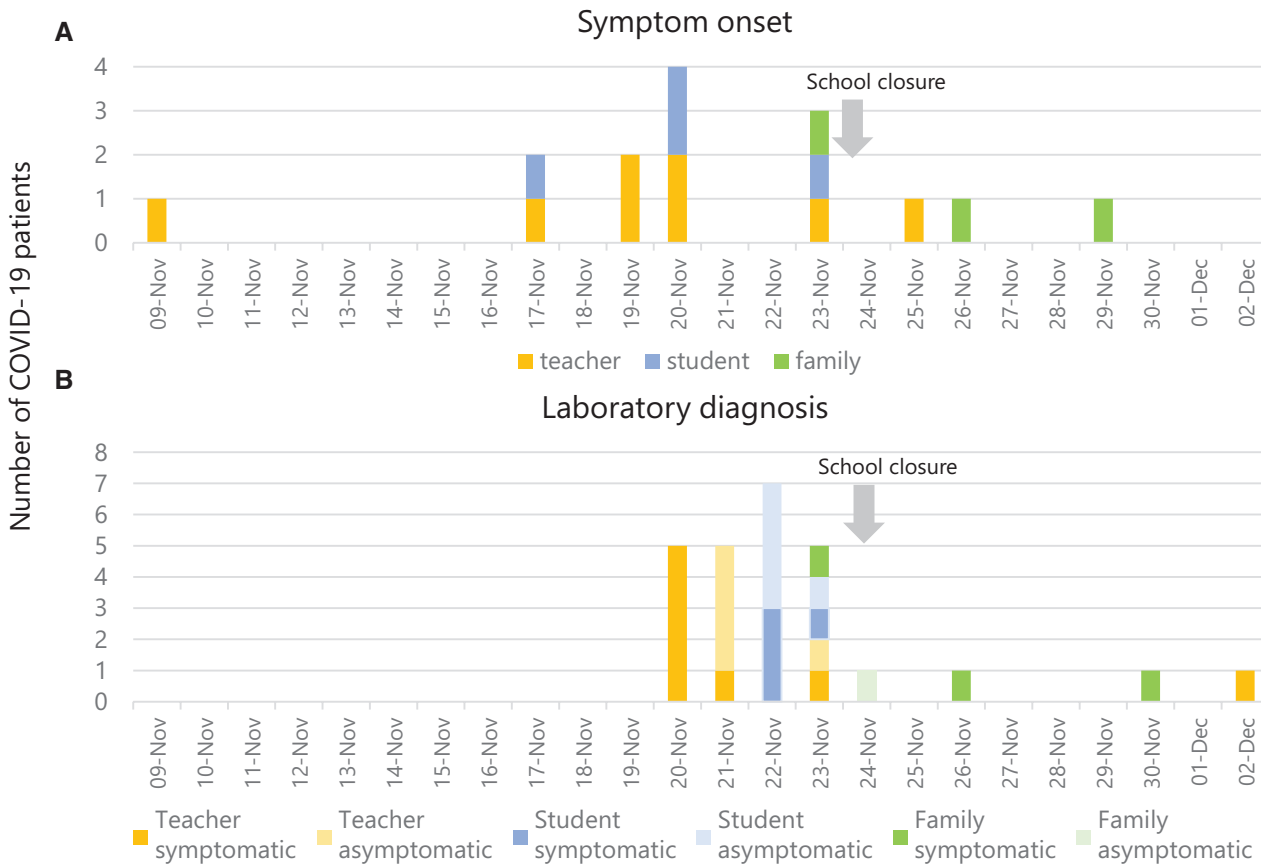

FIGURE 2. Epidemic curve of a school cluster. The figures illustrate symptom onset (A) and laboratory diagnosis (B). COVID-19, coronavirus disease 2019.

cases at schools (primary through high school) between August and November 2020. Among them, no transmission was confirmed in 78%, and 5 or more secondary transmissions was observed in only 3%. The highest rate of COVID-19 outbreak with 5 or more infected persons was at high schools (0.75%), compared with the lowest rate at primary schools (0.06%).[11] A similar trend was also observed in Italy.[24,25] Thus, older children seem important to determine COVID-19 transmission. The present primary school cluster was one of the largest; it affected 23 contacts, and the high secondary attack rate of 33% is notable, as it is higher than the household secondary attack rate (17%).[26] In contrast to the high secondary attack rate among teachers (33%), the transmission rate from infected teachers-to-students was low (4%). Among the 6 classroom teachers, 4 (67%) did not infect students. The probable transmission of COVID-19 in 55 school outbreaks in the UK occurred from teachers-to-teachers in 47% and from teachers-to-students in 15%, from students-to-teachers in 29%, and from students-to-students in 9%.[7] In the present study, transmission was most likely from teachers-to-teachers, followed by teachers-to-students, and teachers/students-to-their family members (Fig. 3). No student-to-student transmission was identified. The main transmission from teachers-to-teachers might contribute to a significant large outbreak at a primary school.

TABLE 1. Characteristics, Symptoms and Laboratory Diagnosis of Patients in a School Cluster of COVID-19

	Total (n = 26)	Teachers (n = 13)	Students (n = 9)	Family members (n = 4)
Age median (range)	37 (8–67)	48 (26–57)	9 (8–12)	55 (32–67)
Male sex	14 (54)	5 (38)	7 (78)	2 (50)
Asymptomatic	11 (42)	5 (38)	5 (56)	1 (25)
Symptomatic	15 (58)	8 (62)	4 (44)	3 (75)
Fever	12 (46)	6 (46)	3 (33)	3 (75)
Sore throat	7 (27)	4 (31)	1 (11)	2 (50)
Cough	4 (15)	2 (15)	0 (0)	2 (50)
Nasal congestion	2 (8)	2 (15)	0 (0)	0 (0)
Headache	2 (8)	0 (0)	0 (0)	2 (50)
Hoarseness	1 (4)	1 (8)	0 (0)	0 (0)
Abdominal pain	1 (4)	0 (0)	1 (11)	0 (0)
Joint pain	1 (4)	1 (8)	0 (0)	0 (0)
Taste dysfunction	1 (4)	1 (8)	0 (0)	0 (0)
Diagnostic assay				
RT-PCR	24 (92)	12 (92)	8 (89)	4 (100)
Rapid antigen test	2 (8)	1 (8)	1 (11)	0 (0)

Data are shown as number (percentage) unless otherwise indicated.

COVID-19 indicates coronavirus disease 2019; RT-PCR, reverse transcription polymerase chain reaction.

The main trigger of this cluster was teachers who continued working while symptomatic. The shortage of teachers in Japan has long been a problem, and we assume that the symptomatic teacher hesitated to take sick leave because of the difficulty in finding a substitute teacher. Flexible attendance and sick leave policies are needed to ensure safe school openings.[11,12] Lowering the threshold for COVID-19 laboratory testing of school teachers might be prudent because adults are drivers of COVID-19 transmission to children.[22] Actually, the teachers were the main source of the COVID-19 clusters at primary schools in the US.[27] A prospective study of

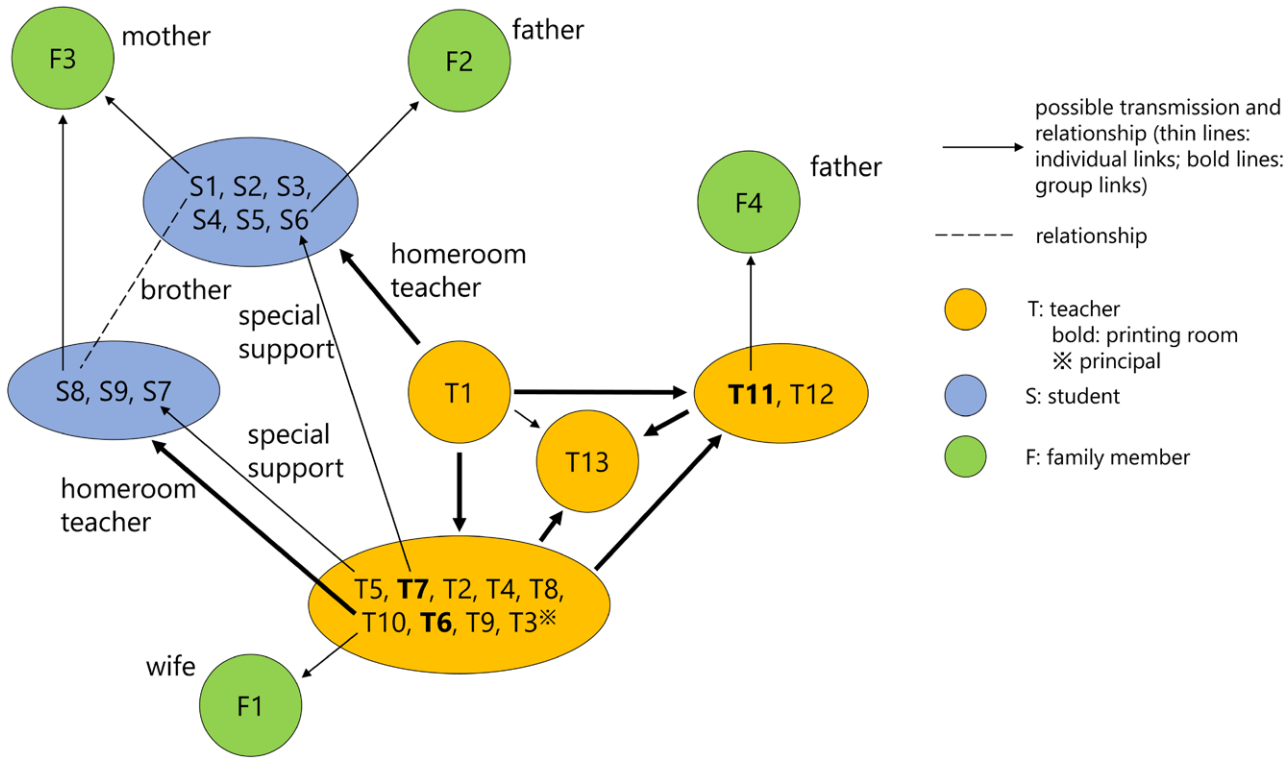

FIGURE 3. Possible transmission and relationships between patients with coronavirus disease 2019 in a school cluster. Teachers T5 and T7 provided individualized support for student S7, who had autism spectrum disorder and S6, who had attention deficit hyperactivity disorder.

Norwegian primary schools revealed minimal child-to-child (1%) and child-to-adult (2%) transmission, suggesting that children are not drivers of COVID-19 transmission at school.[13] It was also reported that a symptomatic COVID-19-infected child with close contacts in 3 different schools did not transmit the disease.[9] These facts are in contrast to the equivalence of pediatric viral load and shedding in the upper respiratory tract in adults.[28,29] It is advisable to establish a system in which symptomatic teachers will not hesitate to remain home and can receive support from other teachers or teach their classes online. Infection prevention among teachers is crucial in preventing school clusters of COVID-19. Such measures should focus on avoiding any risks by teachers and on identifying teachers with mild symptoms during the COVID-19 pandemic.

The inadequate environmental conditions and infection control procedures in the teachers' room spurred COVID-19 transmission among teachers. The "three Cs", that is, closed spaces with poor ventilation, crowded places and close-contact settings, are the main components for a SARS-CoV-2 superspreader event.[30] Such events have had a major role in COVID-19 transmission; in fact, 19% of patients were responsible for 80% of all transmission events in Hong Kong, while 69% of patients did not infect others.[31] The teachers' room of this school cluster met all of the "three Cs". SARS-CoV-2 is primarily transmitted by respiratory droplets during face-to-face contact; thus, a face mask can reduce transmission.[32] Inadequate use of face masks might have contributed to further transmission of COVID-19 in this school cluster. The exemption of face masks due to an extreme heatwave at a high school in Israel combined with crowded classes with symptomatic students caused a large COVID-19 outbreak.[33] Notably, the infected teachers were not located in a specific area of the room (see Figure, Supplemental Digital Content 5, http://links.lww.com/INF/E543). Epidemiologic observation indicates that airborne transmission of SARS-CoV-2 is possible, especially when ventilation is inadequate.[34] Insufficient ventilation of the teachers' room might explain the scattered positioning of the infected teachers. To address the problem of crowded, close-contact settings, schools should ensure adequate teacher distancing or put partitions between desks, to avoid droplets from nearby teachers, or arrange the desks to avoid face-to-face interaction in teachers' rooms. A prospective study of Australian schools found that teachers and students did not significantly contribute to COVID-19 transmission at schools with effective case-contact testing and epidemic management strategies.[10] Likewise, secondary COVID-19 transmission was extremely rare at a US school with in-person instruction.[8] In Sweden, schools have been kept open during the COVID-19 pandemic. The incidence of severe COVID-19 in students has been low, and the relative risk for teachers was lower than for other occupations, excluding healthcare workers.[35]

Notably, nearly half of the students with COVID-19 in this school cluster needed special educational support. Frequent close contact is inevitable for teachers who provide special support for children. Nevertheless, the principles of infection control for teachers in this situation remain the same, namely, to reduce student direct exposure to droplets by the correct use of face masks and avoidance of face-to-face talking and loud speaking with students.

This cluster was caused by lineage B.1.1.214, which does not have currently spreading mutations in the spike protein, such as N501Y and E484K. The phylogenetic tree analysis suggested that 4 strains including B.1.1, B.1.1.214, B.1.1.284 and R.1 were circulating in Niigata Prefecture and that the independent virus strain in B.1.1.214 caused the school cluster (see Figure, Supplemental Digital Content 4, http://links.lww.com/INF/E543).

This study was limited by the nature of the study design. We were unable to enroll patients prospectively and genotype all the virus strains. We were also unable to clarify the actual transmission routes in school, and the reasons why some teachers were infected, and some were not.

In conclusion, because children with SARS-CoV-2 are usually infected by adults, teachers are the key not to spread the virus in school. Our experience with a school cluster originating in a teachers' room has yielded important information on the safe opening of schools.

ACKNOWLEDGMENTS

The authors thank Yoshihiko Nagase, DDS, the director of the local health center, for supporting the study, Makoto Kuroda, PhD, at the Pathogen Genomics Center, the National Institute of Infectious Diseases in Japan, for the whole-genome sequencing, and David Kipler for editing the manuscript.

REFERENCES

1. Buonsenso D, Roland D, De Rose C, et al. Schools closures during the COVID-19 pandemic: a catastrophic global situation. *Pediatr Infect Dis J*. 2021;40:e146–e150.
2. Jackson C, Mangtani P, Hawker J, et al. The effects of school closures on influenza outbreaks and pandemics: systematic review of simulation studies. *PLoS One*. 2014;9:e97297.
3. Viner RM, Bonell C, Drake L, et al. Reopening schools during the COVID-19 pandemic: governments must balance the uncertainty and risks of reopening schools against the clear harms associated with prolonged closure. *Arch Dis Child*. 2021;106:111–113.
4. Munro APS, Faust SN. Children are not COVID-19 super spreaders: time to go back to school. *Arch Dis Child*. 2020;105:618–619.
5. Naimark D, Mishra S, Barrett K, et al. Simulation-based estimation of SARS-CoV-2 infections associated with school closures and community-based nonpharmaceutical interventions in Ontario, Canada. *JAMA Netw Open*. 2021;4:e213793.
6. Hobbs CV, Martin LM, Kim SS, et al; CDC COVID-19 Response Team. Factors associated with positive SARS-CoV-2 test results in outpatient health facilities and Emergency Departments Among Children and adolescents aged <18 years - Mississippi, September-November 2020. *MMWR Morb Mortal Wkly Rep*. 2020;69:1925–1929.
7. Ismail SA, Saliba V, Lopez Bernal J, et al. 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;21:344–353.
8. Zimmerman KO, Akinboyo IC, Brookhart MA, et al. Incidence and secondary transmission of SARS-CoV-2 infections in schools. *Pediatrics*. 2021;147:e2020048090.
9. Danis K, Epaulard O, Bénet T, et al.; Investigation Team. Cluster of Coronavirus Disease 2019 (COVID-19) in the French Alps, February 2020. *Clin Infect Dis*. 2020;71:825–832.
10. Macartney K, Quinn HE, Pillsbury AJ, et al.; NSW COVID-19 Schools Study Team. Transmission of SARS-CoV-2 in Australian educational settings: a prospective cohort study. *Lancet Child Adolesc Health*. 2020;4:807–816.
11. Ministry of Education, Culture, Sports, Science and Technology, Japan. The manual of infection prevention and contorl of novel coronavirus infection at schools. December 3, 2020. Available at: https://www.mext.go.jp/a_menu/coronavirus/mext_00029.html. Accessed April 7, 2021.
12. World Health Organization. Key Messages and Actions for COVID-19 Prevention and Control in Schools. March, 2020. Available at: https://www.who.int/docs/default-source/coronaviruse/key-messages-and-actions-for-covid-19-prevention-and-control-in-schools-march-2020.pdf?sfvrsn=baf81d52_4. Accessed April 7, 2021.
13. Brandal LT, Ofitserova TS, Meijerink H, et al. Minimal transmission of SARS-CoV-2 from paediatric COVID-19 cases in primary schools, Norway, August to November 2020. *Euro Surveill*. 2021;26:2002011.
14. Patel S, Epalza Ibarrondo C, Toubiana J, et al. Urgent need to develop evidence-based COVID-19 recommendations for primary schools [published online ahead of print November 29, 2020]. *Arch Dis Child*. doi: 10.1136/archdischild-2020-321017
15. Gettings JR, Gold JAW, Kimball A, et al. SARS-CoV-2 transmission in a Georgia school district - United States, December 2020-January 2021 [published online ahead of print April 17, 2021]. *Clin Infect Dis*. doi: 10.1093/cid/ciab332
16. Niigata Prefecture. Population based on national census. October, 2020. Available at: https://www.pref.niigata.lg.jp/site/tokei/jinkou20201001.html. Accessed April 7, 2021.
17. Niigata Prefectural Board of Education, Japan. The report on Basic Research on School. 2020. Available at: https://www.pref.niigata.lg.jp/site/kyoiku/gakkoukihon-sokuhou-kyouikuiinkai.html. Accessed April 7, 2021.
18. Idogawa M, Tange S, Nakase H, et al. Interactive web-based graphs of coronavirus disease 2019 cases and deaths per population by country. *Clin Infect Dis*. 2020;71:902–903.
19. Shirato K, Nao N, Katano H, et al. Development of genetic diagnostic methods for detection for novel coronavirus 2019(nCoV-2019) in Japan. *Jpn J Infect Dis*. 2020;73:304–307.
20. O'Toole Á, Scher E, Underwood A, et al. pangolin: lineage assignment in an emerging pandemic as an epidemiological tool. 2020. Availavle at: github.com/cov-lineages/pangolin. Accessed Jul 4, 2021.
21. Kumar S, Stecher G, Tamura K. MEGA7: molecular evolutionary genetics analysis version 7.0 for bigger datasets. *Mol Biol Evol*. 2016;33:1870–1874.
22. Zhu Y, Bloxham CJ, Hulme KD, et al. A meta-analysis on the role of children in SARS-CoV-2 in household transmission clusters [published online ahead of print December 6, 2020]. *Clin Infect Dis*. 2021;72:e1146-e1153.
23. Miyahara R, Tsuchiya N, Yasuda I, et al. Familial clusters of coronavirus disease in 10 prefectures, Japan, February-May 2020. *Emerg Infect Dis*. 2021;27:915–918.
24. Buonsenso D, Graglia B. High rates of SARS-CoV-2 transmission in a high-school class. *J Paediatr Child Health*. 2021;57:299–300.
25. Buonsenso D, De Rose C, Moroni R, et al. SARS-CoV-2 infections in Italian schools: preliminary findings after 1 month of school opening during the second wave of the pandemic. *Front Pediatr*. 2020;8:615894.
26. Fung HF, Martinez L, Alarid-Escudero F, et al. The household secondary attack rate of SARS-CoV-2: a rapid review [published online ahead of print October 12, 2020]. *Clin Infect Dis*. 2021;73(Suppl 2):S138-S145.
27. Gold JAW, Gettings JR, Kimball A, et al.; Georgia K–12 School COVID-19 Investigation Team. Clusters of SARS-CoV-2 infection among elementary School Educators and Students in One School District - Georgia, December 2020-January 2021. *MMWR Morb Mortal Wkly Rep*. 2021;70:289–292.
28. Han MS, Choi EH, Chang SH, et al. Clinical characteristics and viral RNA detection in children with coronavirus disease 2019 in the Republic of Korea. *JAMA Pediatr*. 2021;175:73–80.
29. Yonker LM, Neilan AM, Bartsch Y, et al. Pediatric severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2): clinical presentation, infectivity, and immune responses. *J Pediatr*. 2020;227:45–52.e5.
30. Furuse Y, Sando E, Tsuchiya N, et al. Clusters of coronavirus disease in communities, Japan, January-April 2020. *Emerg Infect Dis*. 2020;26:2176–2179.
31. Adam DC, Wu P, Wong JY, et al. Clustering and superspreading potential of SARS-CoV-2 infections in Hong Kong. *Nat Med*. 2020;26:1714–1719.
32. Chu DK, Akl EA, Duda S, et al; COVID-19 Systematic Urgent Review Group Effort (SURGE) study authors. Physical distancing, face masks, and eye protection to prevent person-to-person transmission of SARS-CoV-2 and COVID-19: a systematic review and meta-analysis. *Lancet*. 2020;395:1973–1987.
33. Stein-Zamir C, Abramson N, Shoob H, et al. A large COVID-19 outbreak in a high school 10 days after schools' reopening, Israel, May 2020. *Euro Surveill*. 2020;25:2001352.
34. de Man P, Paltansing S, Ong DSY, et al. Outbreak of coronavirus disease 2019 (COVID-19) in a nursing home associated with aerosol transmission as a result of inadequate ventilation. *Clin Infect Dis*. 2021;73:170–171.
35. Ludvigsson JF, Engerström L, Nordenhäll C, et al. Open schools, Covid-19, and child and teacher morbidity in Sweden. *N Engl J Med*. 2021;384:669–671.