

# Cluster of Severe Acute Respiratory Syndrome Coronavirus 2 Infections Linked to Music Clubs in Osaka, Japan

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**Background.** It is important to understand the mode of transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) for disease control. We aimed to clarify how soon SARS-CoV-2 transmission can occur after infection by asymptotically infected individuals.

**Methods.** We analyzed the publicly available epidemiological information for a cluster of 108 cases of coronavirus disease 2019 (COVID-19) cases in Osaka, Japan.

**Results.** Among cases, 51 cases attended a live music club only once and were considered to have a single visit. Ten remained asymptomatic at the time of COVID-19 diagnosis by reverse-transcription polymerase chain reaction, which was on average 20 days after exposure. Three routes of secondary transmission were identified, with 2–4 days from infection to transmission. All index cases for secondary transmission were asymptomatic at the time of contact with other people. Based on the date of symptom onset in the remaining 41 cases, the period from exposure to illness ranged from 2 to 17 days.

**Conclusions.** Seemingly healthy people could spread SARS-CoV-2 during intense activities in enclosed environments without sufficient ventilation. Asymptotically infected persons can transmit the virus as soon as 2 days after infection. Continuous efforts to avoid crowding and to maintain personal hygiene are needed for effective control of COVID-19.

**Keywords.** descriptive epidemiology; virus transmission; coronavirus disease 2019; COVID-19; severe acute respiratory syndrome coronavirus 2; SARS-CoV-2.

An epidemic of coronavirus disease 2019 (COVID-19) caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) broke out in Wuhan, Hubei, China, in December 2019 [1]. In the early days of the COVID-19 outbreak, direct contact with intermediate host animals or the consumption of wild animals was suspected to be the main route of SARS-CoV-2 transmission [1]. However, human-to-human transmission of SARS-CoV-2 became apparent between family members, relatives, and friends who had close contact with symptomatic patients or asymptomatic SARS-CoV-2-infected individuals [2–11]. SARS-CoV-2 spreads mainly through respiratory droplets or close contact.

The first COVID-19 case in Japan was a man in his 30s who returned from Wuhan to Japan on 6 January 2020 and was publicly reported to be infected with SARS-CoV-2 on 16 January [12]. The

Japanese government added COVID-19 to the list of designated infectious diseases under the Infectious Disease Law, which allows authorities to conduct compulsory hospitalization of infected patients and stop them from attending work. COVID-19 was also designated as a quarantinable infectious disease under the Quarantine Law. On 27 February 2020, a case was identified in Osaka, Japan, with no history of foreign travel or apparent contact with a patient with COVID-19 infection within 14 days before the onset of symptoms [13]. This led to the identification of a cluster of 108 cases that had a positive reverse-transcription polymerase chain reaction (RT-PCR) test result. This first cluster of COVID-19 cases in Osaka had a notable feature in that the explosive spread primarily occurred in 4 live music clubs during the very early stage of the epidemic in Japan. A team of cluster investigation experts comprising members from local public health centers, the National Institute of Infectious Diseases (NIID), and the Japanese Ministry of Health, Labour and Welfare (MHLW) thoroughly tracked the close contacts of these cases and publicly reported the data. Owing to their efforts, the cluster was successfully contained by 17 March 2020.

Most cluster investigations of COVID-19 reported so far have implicated familial or nosocomial transmissions in which the time of exposure was difficult to identify [2–11]. By contrast, in this Osaka cluster, there were many cases reporting visits to the music clubs as a potential source of infection; this circumstance can

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provide very useful clues regarding the transmission and characteristics of this disease. The purpose of this study was to clarify the period from initial exposure to being able to transmit SARS-CoV-2 and the role of asymptomatic cases in transmission by analyzing the publicly available epidemiological data of this Osaka cluster.

## METHODS

### Data Source

Since 16 January 2020, the Japanese MHLW has publicly released the anonymized information of incident COVID-19 cases with a positive RT-PCR test result [14]. The information comprises patient characteristics including sex, age group (10-year categories), area of residence, symptoms, date of symptom onset, source of exposure and contacts, and the date of a positive RT-PCR test.

The investigation was conducted by the local public health centers with technical advice provided by the NIID and MHLW, as necessary. The date of symptom onset was defined as the date when patients become aware of any of the following acute symptoms: fever, cough, difficulty breathing, fatigue, sore throat, runny nose/nasal congestion, headache, arthralgia/myalgia, diarrhea, or nausea/vomiting.

All RT-PCR tests were performed at the local public health institution (ie, governmental laboratory) that covered the areas

where each case lived, using primers and a standardized protocol distributed by the NIID [15].

To evaluate the plausible period from exposure to symptom onset, 51 cases were selected who had attended 1 music concert only and were therefore considered as having a single visit (Figure 1). To estimate the potential time window from initial exposure to becoming infectious, we focused on cases that had attended 2 or more clubs. We also investigated the potential transmissibility from asymptomatic cases who had not become symptomatic by the time of RT-PCR testing.

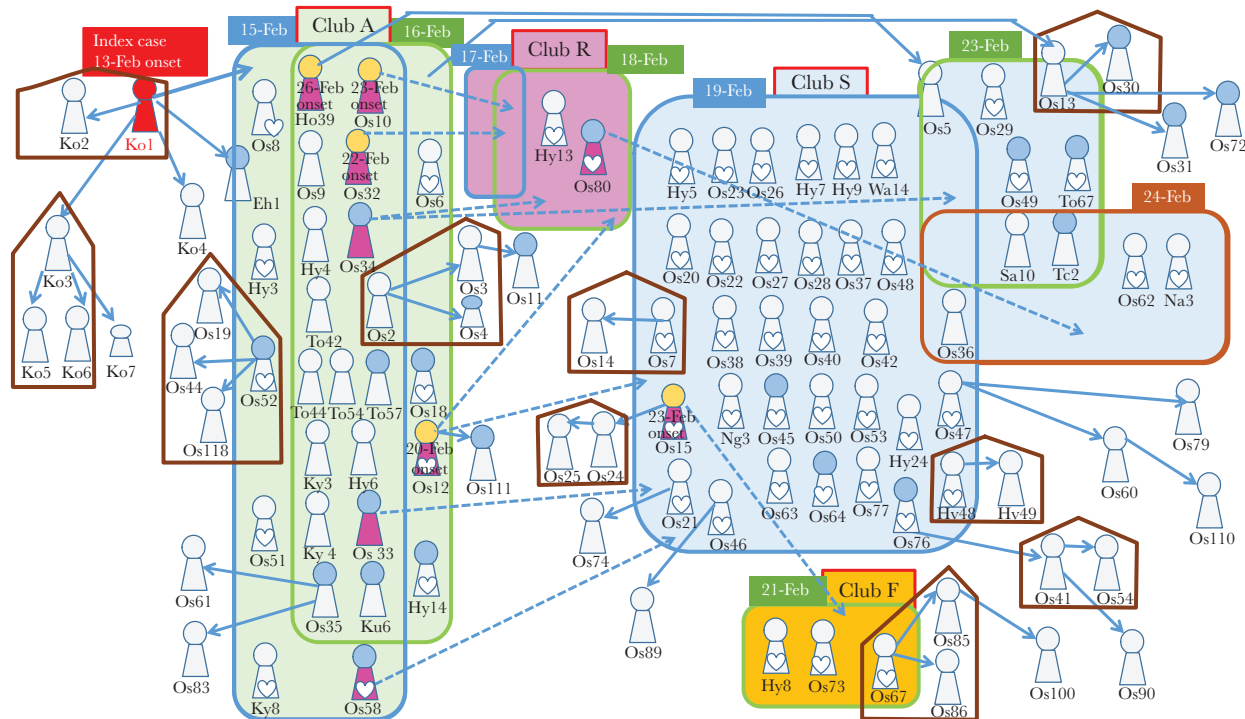
### Ethical Considerations

Because we used publicly available anonymous data, neither informed consent nor approval from the ethics committee was required according to the ethical guidelines for human research in Japan.

## RESULTS

### Study Population

The data of 108 cases comprising the Osaka cluster that were linked to various music clubs were extracted from the MHLW website [14]. A complete list of these cases is provided in Supplementary Table 1. The cases included 70 female and 38



**Figure 1.** Diagram showing contact relationships of the 108 cases. Pink figures indicate secondary index cases who attended 2 or more clubs. Cases with a blue face were still asymptomatic at the time of cluster surveillance and reverse-transcription polymerase chain reaction testing. Dates of symptom onset in the index cases for secondary transmission are shown in the figure. Figures with a heart indicate the 51 cases who had a single visit. Pentagons indicate families. The 4 different clubs are indicated by different colored square; the different colored outlines indicate the date of the live music concert. Arrows with a solid line indicate personal contact, and arrows with a dotted line indicate transmission that occurred at the club. The prefecture of residence for each case is described with an abbreviation, as follows: Eh, Ehime; Ho, Hokkaido; Hy, Hyogo; Ko, Kochi; Ku, Kumamoto; Ky, Kyoto; Na, Nara; Ng, Nagano; Os, Osaka; Sa, Saitama; Tc, Tochigi; To, Tokyo; Wa, Wakayama.

male individuals. The age distribution ranged from 0-9 years to 70-79 years, with the mean age group 40-49 years. There were 79 symptomatic cases (73%: n = 51 female, n = 28 male), 23 asymptomatic cases (21%: n = 15 female, n = 8 male) at the time of RT-PCR testing, and 6 uncertain cases (6%: n = 4 female, n = 2 male). The epidemic curve of the 108 cases is shown in Figure 2, together with the total cases in Japan and those in 3 prefectures (Osaka, Hyogo, and Kyoto). Most cases in the Osaka cluster lived in 1 of these 3 prefectures, which are geographically close to each other.

All cases were plotted as shown in Figure 1, to help clarify the relationship between source cases and those infected by a source case, as well as to determine the date and place of exposure. Four locations where substantial exposure could have occurred were identified, along with 8 time points, as follows: 15 and 16 February in Club A; 17 and 18 February in Club R; 19, 23, and 24 February in Club S; and 21 February in Club F. The index case in this cluster was a woman in her 30s from Kochi Prefecture (Ko1) [16]. She developed a sore throat on 13 February. She worked at a hospital, and 1 of her coworkers became the third case of COVID-19 infection in Kochi Prefecture (Ko3). This third case had contact with the index case only on 14 February in the hospital before illness onset on 24 February. The index case went to Osaka with her friend (Eh1) on 15 February, where they attended a concert at Club A that evening. In total, 23 individuals became infected at that the club on that night, and 17 of them subsequently attended a music concert at Club A the following evening (16 February), at which the index case was absent. Four additional cases who went to Club A only on 16 February became infected. The possible mode of the subsequent spread of infection is depicted in Figure 1.

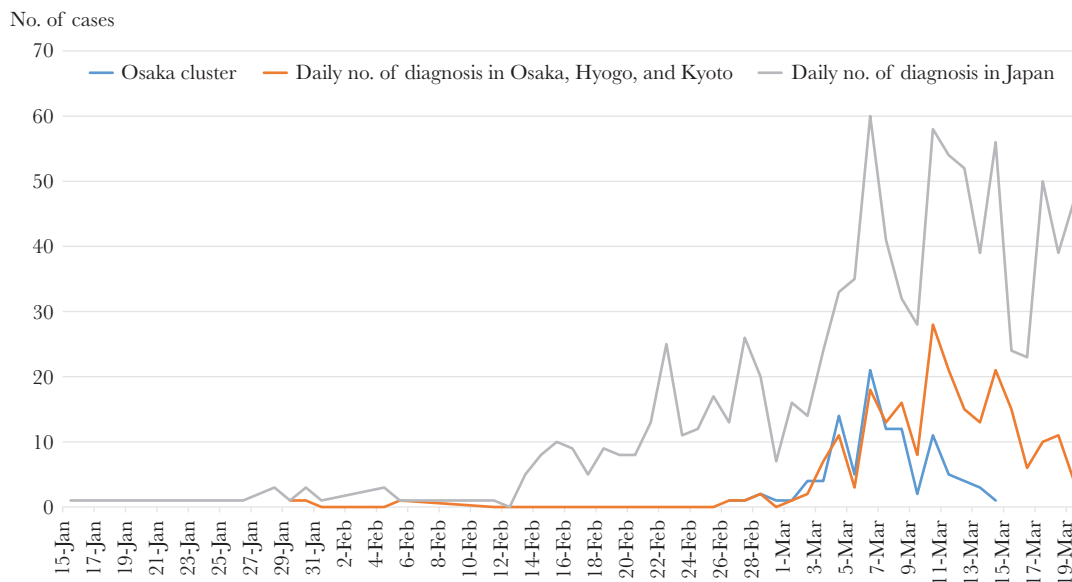
### Period From Exposure to Symptom Onset

Among the 51 cases with a single visit, 6 attended Club A on 15 February, 4 attended Club A on 16 February, 2 attended Club R on 18 February, 31 attended Club S on 19 February, 3 attended Club F on 21 February, 3 attended Club S on 23 February, and 2 attended Club S on 24 February (Figure 1 and Supplementary Table 1). Ten of these individuals (Os18, Os45, Os49, Os52, Os58, Os64, Os67, Os76, Os80, and Hy14) were still asymptomatic at the time of cluster surveillance and RT-PCR testing. For these 10 asymptomatic cases, a positive RT-PCR test result was obtained within an average of 20 days (range, 14-22 days) after exposure. In the remaining 41 symptomatic cases, the date of onset was known for 40 cases; the period from exposure to onset ranged from 2 to 17 days, with a median of 7 days. Three of these symptomatic cases had a period >14 days from exposure to becoming symptomatic (Supplementary Table 1).

### Potential Time Window From Exposure to Becoming Infectious

To estimate the time window from being infected to becoming infectious, we focused on 8 cases who attended 2 or more clubs (Os10, Os12, Os15, Os32, Os33, Os34, Os58, and Os80; Figure 1); these cases were defined as the index cases for secondary transmission.

Four Club A-related cases also attended Club R. Two of them attended Club A on both 15 and 16 February (Os10 and Os32) and went to Club R on 17 and 18 February. One of these individuals who attended Club A on both 15 and 16 February (Os34) and another case who attended Club A on 16 February (Os12) went to Club R on 18 February. All cases were asymptomatic when attending Club R on 18 February. However, Os10 and Os32 became symptomatic on 23 and 22 February, respectively;



**Figure 2.** Epidemic curve of 108 cases together with total cases in Japan and those in the 3 prefectures (Osaka, Hyogo, and Kyoto) where most cases in the Osaka cluster lived; these prefectures are geographically close to each other.

Os34 remained asymptomatic, despite a positive RT-PCR test, and Os12 became symptomatic on 20 February. Therefore, the 4 asymptotically infected cases likely transmitted the virus to 2 people (Hy13 and Os80) within 2–3 days after exposure.

Four Club A–related cases went to Club S on 19 February, and 32 cases became infected on that day. One of these 4 cases (Os58) attended Club A only on 15 February, another (Os12) attended on 16 February, and the remaining 2 (Os33 and Os34) attended on both 15 and 16 February. Three cases (Os33, Os34, and Os58) were still asymptomatic at the time of RT-PCR testing, whereas Os12 developed symptoms on 20 February. These data suggest that the disease transmission occurred from 4 asymptomatic cases when attending Club S within 3–4 days after they were exposed.

One case (Os15) attended Club S on 19 February and then went to Club F on 21 February, where 3 cases became infected. This individual was still asymptomatic on 21 February. This suggests that a person with asymptomatic SARS-CoV-2 infection is contagious as soon as 2 days after infection.

One case (Os80) attended Club R on 18 February and then went to Club F on 24 February, where 2 cases became infected. Os80 was still asymptomatic at the time of RT-PCR testing. However, this case was not included in the analysis of the time window from exposure to becoming infectious because there were other potential sources of infection in Club S on 24 February (Os36, Sa10, and Tc2).

#### Proportion of Cases With Asymptomatic Virus Transmission

Among the 72 cases who had a possible exposure only from attending 1 of the 4 clubs and who became infected, 23 (32%) who attended a live concert in Club A on 15 February were infected by the symptomatic index case (Ko1). For 4 cases who attended Club A only on 16 February, the transmission route could not be determined because it is possible that they became infected via environmental viral contamination at the concert held in Club A on 15 February. Regarding 5 cases who attended Club S on 23 February and became infected, there were 2 possible transmission routes: via exposure to asymptomatic individuals with SARS-CoV-2 infection who were also in attendance (Os13 and Os34), or via a symptomatic case in attendance (Os5). Thus, the transmission source of the 2 cases who attended Club S only on 24 February could not be determined. The remaining 38 cases (53%) who attended the other 3 clubs likely became infected through exposure to asymptomatic cases of SARS-CoV-2 infection.

#### Transmission Outside the Clubs

Apart from the music club, transmission occurred via either family members or coworkers of the infected cases. The maximum number of people infected by each case was 3, and positive RT-PCR test results were limited to within 2 additional transmission generations. The maximum asymptomatic

duration was defined as the duration from the day of attending the music club to the day of the detection of SARS-CoV-2 by RT-PCR in asymptomatic cases. Among cases who attended the music clubs, 3 cases (Os35, Os52, and Os76) had not become symptomatic by the time of RT-PCR testing (Figure 1 and Supplementary Table 1), indicating that the maximum duration of their ability to infect others asymptotically was 21–22 days after infection.

## DISCUSSION

In this study, we identified 3 routes of secondary transmission linked to music clubs in Osaka, Japan, and found that all of the index cases for secondary transmission were asymptomatic at the time of contact with other people. Asymptomatic individuals with SARS-CoV-2 infection were able to transmit the virus from 2 to 4 days after infection. Based on the date of onset of COVID-19 symptoms, the period from exposure to symptom onset ranged from 2 to 17 days.

Transmission from asymptomatic SARS-CoV-2 exposure has been well documented [17], although it is unclear to what extent such transmission contributes to the overall spread of infection [6, 7, 18–20]. This study revealed that most asymptomatic cases obtained a positive RT-PCR test result an average of 20 days (14–22 days) after the initial infection, whereas the duration from infection to illness onset in symptomatic patients was 2–17 days. Therefore, individuals with no onset of symptoms were considered to be asymptomatic cases.

This was a study of the first cluster of 108 cases with COVID-19 in Osaka in which substantial exposure occurred within a few hours at a music club. This cluster analysis provides insight regarding the course of virus transmission, including the period from initial exposure to becoming symptomatic, the period from initial exposure to becoming infectious, and the contribution of asymptomatic cases to the spread of SARS-CoV-2.

We focused on cases who attended 2 or more clubs to estimate the period from exposure to becoming able to transmit SARS-CoV-2. When we considered the earliest date of club attendance as the date of exposure, 4 asymptomatic cases who attended Club A and later attended Club R (Os10, Os12, Os32, and Os34) were found to have transmitted SARS-CoV-2 to 2 people (Hy13 and Os80) within 2–3 days after infection. Three asymptomatic cases (Os33, Os34, and Os58) and 1 additional asymptomatic case (Os 12) who went to Club A and later Club S were found to have spread SARS-CoV-2 to 32 people within 3–4 days after infection. One asymptomatic case (Os15) had the shortest period from exposure to transmission, infecting 3 people 2 days after he was infected. Overall, these findings suggest that the viral load can become sufficiently high to permit SARS-CoV-2 transmission 2 days after infection. Regarding the 4 infected cases who attended Club A only on 16 February, it is possible that someone who attended Club A on 15 February transmitted the virus to



them within 1 day after infection. Generally, no specific disinfection for SARS-CoV-2 (eg, using alcohol spray) was carried out in February 2020 in Japan, and it is possible that some surfaces at Club A were still contaminated with the virus on 16 February. Therefore, considerable environmental contamination via respiratory droplets from the initial symptomatic patient carrying SARS-CoV-2 might have also served as the mechanism of transmission in Club A.

From our results, it is reasonable to believe that the spread of SARS-CoV-2 initially occurred in the 4 music clubs. Although the 23 visitors on the first day in Club A became infected by the symptomatic index case, the other 38 cases (53%) were infected in the other 3 clubs via asymptomatic transmission. Moreover, 3 cases who had not become symptomatic by the time of RT-PCR testing transmitted the virus to their family members and coworkers outside the clubs. Such transmission via asymptomatic exposure is a challenge for containment. Activities including talking or drinking may increase the generation and subsequent spread of respiratory droplets, and an enclosed environment that lacks sufficient ventilation may accelerate virus transmission. All 4 music clubs agreed to alert the public through media outlets about the possible exposure of clients who attended concerts on certain dates and locations. In this way, thorough contact tracing was possible and the cluster was contained. Ko1 wore a face mask at her workplace only once she developed symptoms but was not wearing a mask at the club. In February, general awareness about protection against COVID-19 was low because of the small number of COVID-19 patients in Japan, and mask wearing was not common. Therefore, people who attended the club would not have been wearing a face mask, at least not while drinking; all of those who could potentially be exposed were therefore unprotected, leading to the subsequent spread of SARS-CoV-2 at the clubs. Our findings reconfirm the importance of avoiding gatherings with many people in an enclosed space who are in close contact [21], as well as the importance of proper hand hygiene and face mask use.

In this cluster, 51 cases were considered to have only a single visit. Ten of these cases (10%) were still asymptomatic at the time of cluster surveillance and RT-PCR testing. The period from exposure to disease onset in 40 cases ranged from 2 to 17 days, with a median of 7 days, which is slightly longer than the median incubation period of 5.1 days reported by Lauer et al [22]. Because 3 cases had a period longer than 14 days from exposure to becoming symptomatic, the current length of quarantine might be insufficient in some cases.

There are several limitations to this study. Information was self-reported and some cases may have had different sources of exposure. We do not know whether cases who were still asymptomatic at the time of RT-PCR testing subsequently developed symptoms. Because genome sequencing of SARS-CoV-2 was unavailable, the 108 cases may not have been truly included

in the same cluster, even though they had an epidemiological link. We did not assess the viral load in asymptomatic cases either directly or using a surrogate parameter. Thus, we cannot quantitatively estimate the threshold that may have led to transmission from the asymptomatic cases. Further study is needed to clarify the mechanism of transmission from asymptomatic cases. Finally, this study used information that was originally obtained through an epidemiological cluster investigation carried out under the Infectious Disease Law, which was not related to the research aim. Despite the governmental effort of contacting all potential cases related to the 4 music clubs, we cannot obtain any individual daily evidence of SARS-CoV-2 and cannot completely exclude the possibility that there were additional undetected cases that had a different source of infection. Nonetheless, there were only 34 identified COVID-19 cases by 15 February in Japan, so the chance of infection outside this cluster is considered very unlikely.

From this cluster investigation, we conclude that seemingly healthy people are able to widely spread SARS-CoV-2 during intense activities in enclosed environments without sufficient ventilation. Asymptomatically infected persons can transmit the virus as soon as 2 days after infection. Therefore, continuous efforts to avoid crowding and to maintain personal hygiene are needed for the effective control of COVID-19.

#### Supplementary Data

Supplementary materials are available at *The Journal of 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

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**Potential conflicts of interest.** All authors: No reported conflicts of interest.

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.

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