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MAJOR ARTICLE

A Cluster of Novel Coronavirus Disease 2019 Infections Indicating Person-to-Person Transmission Among Casual Contacts From Social Gatherings: An Outbreak Case-Contact Investigation

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Background. Severe acute respiratory syndrome coronavirus 2, the pathogen causing novel coronavirus disease of 2019 (COVID-19), efficiently spreads from person to person in close contact settings. Transmission among casual contacts in settings such as during social gatherings is not well understood.

Methods. We report several transmission events to both close and casual contacts from a cluster of 7 COVID-19 cases occurring from mid-January to early February 2020. A total of 539 social and family contacts of the index patient's, including members of a 2-day wedding and a family party, were contacted and screened through epidemiologic surveys. The clinical progression of all cases is described.

Results. We estimate the secondary attack rate among close contacts to be 29% (2 of 7) and for the casual contacts to be 0.6% (3 of 473). The incubation period of our case cluster was 4–12 days (median, 7 days).

Conclusions. Transmission efficiency among close contacts was higher than among casual contacts; however, transmission from second-generation cases may help spread the virus during the incubation period.

Keywords. attack rate; casual contact; cluster; COVID-19; social gathering.

The novel coronavirus disease 2019 (COVID-19) first emerged in humans in late 2019 in Wuhan, China [1, 2]. The disease is caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Due to the rapid spread of the disease on a global scale, the World Health Organization escalated the risk assessment of COVID-19 to "very high." Much remains unknown about SARS-CoV-2 transmission. Evidence of human-to-human transmission has been shown from several familial clusters of infections associated with COVID-19 both within and outside of China [3–6]. Although these familial clusters suggest that close contact and sharing of living spaces within a family are an important transmission route, there have been limited reports on the transmission dynamics of COVID-19 from casual contact in the community [1, 7, 8].

Given the large number of infections that occurred in a short time in Wuhan, community spread, eg, in hospitals and other places, is likely. However, whether such community spread has become an important route of transmission in places outside of Hubei province remains to be investigated [7]. In regions outside of Hubei province, index cases have often been linked to recent travel history to Wuhan, or to close contacts of those with recent Wuhan travel histories [8, 9]. Current understanding of community transmission largely relies on anecdotal reports and limited studies with no direct evidence of social or community transmission [8], yet the transmission dynamic and risk associated with social gatherings has not been well documented. A better understanding of the role of community spread through casual contacts in regions outside of Hubei province is important for disease prevention and control [1, 9].

Zhejiang province is among the regions with the highest number of confirmed COVID-19 cases outside of Hubei province in China. We investigate a cluster of infections associated COVID-19 reported from Jiaxing, Zhejiang in January of

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2020. Our study reports detailed epidemiological information to provide direct evidence of person-to-person transmission among casual contacts from social gatherings in a region outside of Hubei province.

METHODS

Study Participants and Data Collection

The cluster under investigation involves 4 confirmed cases from a family (Cases 1–4) and 3 other confirmed cases (Cases 5–7) and 1 suspected case (Case 8) thought to be linked to the familial cluster through social events. Data for the index patient's 8 family members, including 2 source patients, and all attendees in a series of social events that the index patient and the source patients attended over the period of the outbreak were included in the current study. Data collection was through a questionnaire survey and in-person interview conducted by the local Centers for Disease Control and Prevention (CDC) staff in Jiaxing city. The study was approved by the Institute Review Board at the Zhejiang Provincial CDC.

Clinical Examinations and Treatments

Whole blood cell counts, blood biochemical examination, chest radiographic x-ray examinations, and/or computerized tomography (CT) scan were examined to monitor the progression of COVID-19. Symptomatic treatments were implemented for all patients. In addition, data on demographics and disease history were retrieved from medical records.

Epidemiologic Investigation

Extensive case tracking was performed. A total of 539 people who had contact with the 2 cases presumed to be the sources of the outbreak and the index patient were screened. The name list of the 539 patients was provided by the hosts of the weddings and birthday party and the managers at corresponding restaurants, etc. These individuals were contacted by phone and subsequently quarantined in centralized locations for 14 days. During the 14-day period of quarantine, all individuals were asked to measure their own temperatures twice a day, and local department of health staffs would follow-up with each of them through phone in the mornings and afternoons (twice daily) to ask about symptoms including fever, cough, fatigue, and diarrhea, etc. If a patient presented fever, cough, fatigue, diarrhea, or other symptoms, throat swabs (oropharyngeal) were collected upon symptom occurrence for a reverse-transcription polymerase chain reaction (RT-PCR) test and the patient was sent to a designated hospital for chest CT and routine blood tests.

Case Definitions

Confirmed cases were those tested positive for COVID-19 using a RT-PCR test. A suspected case was defined as having an exposure history of COVID-19 and 2 or more clinical manifestations of COVID-19. An individual who met any of the following criteria was considered to have an exposure history of COVID-19: (1) 14 days before symptoms onset, the individual traveled to or returned from Wuhan or other areas where there were reported cases of COVID-19; (2) 14 days before symptoms onset, the individual had contact with patients having fever or respiratory symptoms and having recent travel histories to Wuhan or other areas where there were reported cases of COVID-19; (3) the individual was exposed to an outbreak of COVID-19, with an outbreak of COVID-19 defined as the identification of 2 or more cases in a small region (eg, a family, a construction site, a working place, etc) within 14 days.

Clinical manifestations included (1) fever (>37.5°C), (2) abnormal radiology changes in the lungs suggesting pneumonia, (3) having normal or low white blood cell counts, and/or (4) lower lymphocytes counts in the beginning of the disease. The incubation period was defined as the interval between the earliest date of contact with a source of transmission and the date of symptom onset. The index was defined as the first documented patient in the outbreak.

Contact Definition

We define close contacts as individuals who had close, prolonged, and repeated interactions with the 2 source cases (Cases 2 and 3). All other contacts are defined as casual contacts.

Statistical Analysis

Descriptive analyses were performed to estimate the attack rate of COVID-19 among individuals having close contacts with the index patient and his parents-in-law, the source of this outbreak, and to summarize characteristics of the COVID-19 patients. All statistical analyses were conducted in R 3.6.1 [10].

Ethics Statement

The research protocol was approved by the institutional review board of Zhejiang CDC, and all human participants provided informed consent.

RESULTS

Progressions and Clinical Features of Novel Coronavirus Disease 2019 Patients

On January 25, 2020, a 29-year-old male patient (Case 1 and the index patient) came to the Fever Clinic of Jiaxing01 (we abbreviate each hospital in the outbreak as Jiaxing 01, 02, and 03 for confidentiality reasons) Hospital with a complaint of cough with phlegm for 1 day. A throat swab was collected from the patient and sent to Jiaxing Municipal CDC for RT-PCR testing of COVID-19. The patient also reported that his parents-in-law (Cases 2 and 3) had a travel history to Wuhan, the epicenter of COVID-19, 1 week before the clinical visit. The patient was admitted and quarantined in the Jiaxing 01 Hospital. The next day, Jiaxing CDC reported a positive test result for COVID-19, and the test result was further confirmed by Zhejiang Provincial

CDC on January 27, 2020. A CT scan showed ground-glass opacity and high-density shadow, which suggested viral pneumonia on January 29, 2020. Case 1's body temperature reached 38.1℃ in the morning of January 30, 2020. His chest radiograph suggested progression to pneumonia on February 2, 2020. He was transferred to another hospital on the following day. Epidemiological investigation and contact tracing were performed on close contacts of Case 1 and a cluster of COVID-19 infections were identified subsequently. Progressions of all confirmed and suspected COVID-19 patients are summarized in Figures 1–3, with details on other cases described below.

Case 2, a 51-year-old female, and Case 3, a 55-year-old male, were the parents-in-law of Case 1's. Both Case 2 and Case 3 were admitted to the Jiaxing 01 Hospital for clinical observation and quarantine on January 26, 2020 when the index case tested positive for COVID-19. Case 2 had a fever of 38.5℃ on that day, and her blood test showed low white blood cell counts and lymphocytes counts. Case 3 had low lymphocytes counts and elevated C-reactive protein (CRP). Throat swabs were collected and tested for COVID-19 by the Jiaxing Municipal CDC on January 27, 2020. Case 2 tested positive for COVID-19, but Case 3 tested negative. However, after a second test was performed by the Zhejiang Provincial CDC, in which both Cases 2 and 3 tested positive, they were diagnosed with COVID-19 on January 28, 2020. Although Case 2's body temperature dropped to 36.8℃ on February 3, 2020, imaging evidence of pneumonia was established for both Cases 2 and 3 on the same day.

Case 4, a 4-month-old infant girl and the daughter of Case 1's, was admitted to the Jiaxing 02 Hospital on January 29, 2020 due to a low-grade fever and diarrhea. The infant girl was diagnosed with COVID-19 by the Jiaxing 02 Hospital on January 30, 2020. Of note, the initial clinical manifestations of the 4-month-old

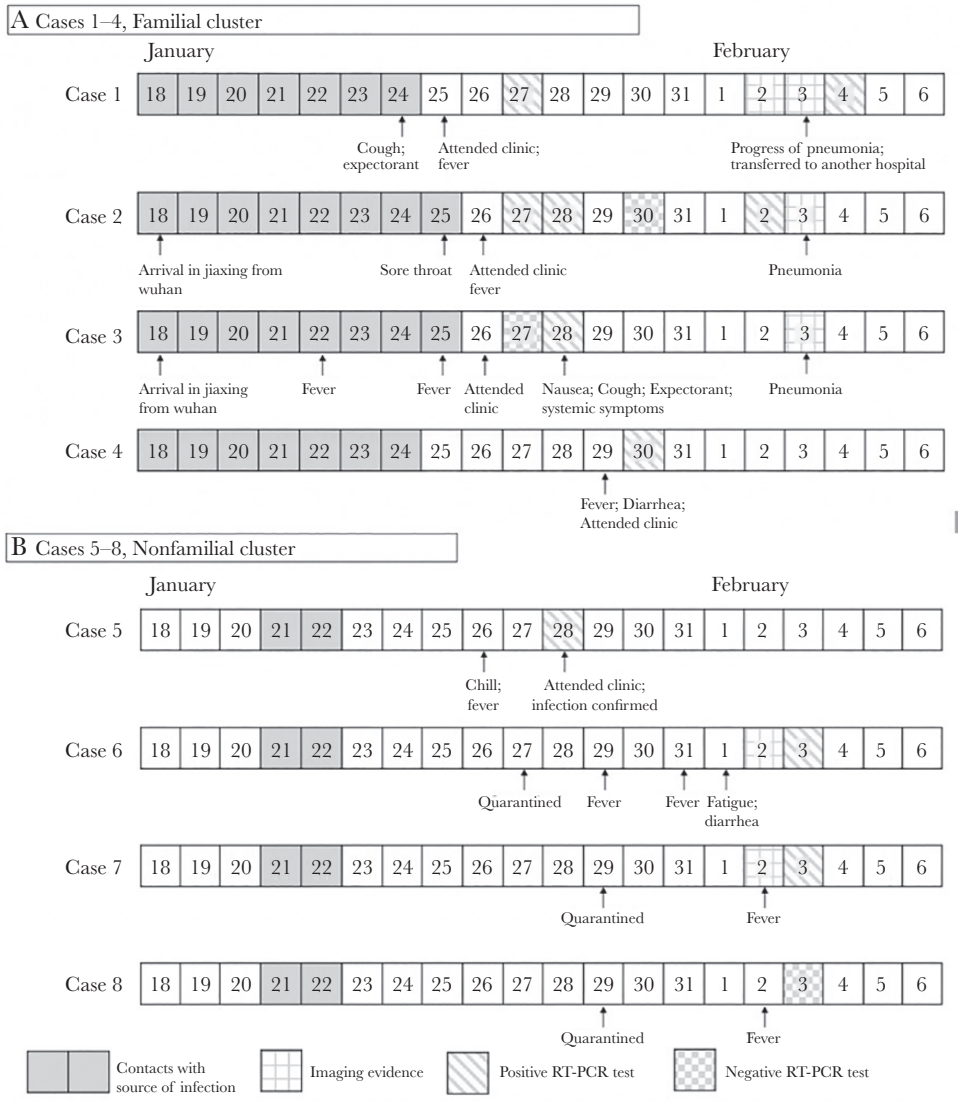

Figure 1. Chronology of symptom onset of familial and nonfamilial clusters. RT-PCR, reverse-transcription polymerase chain reaction.

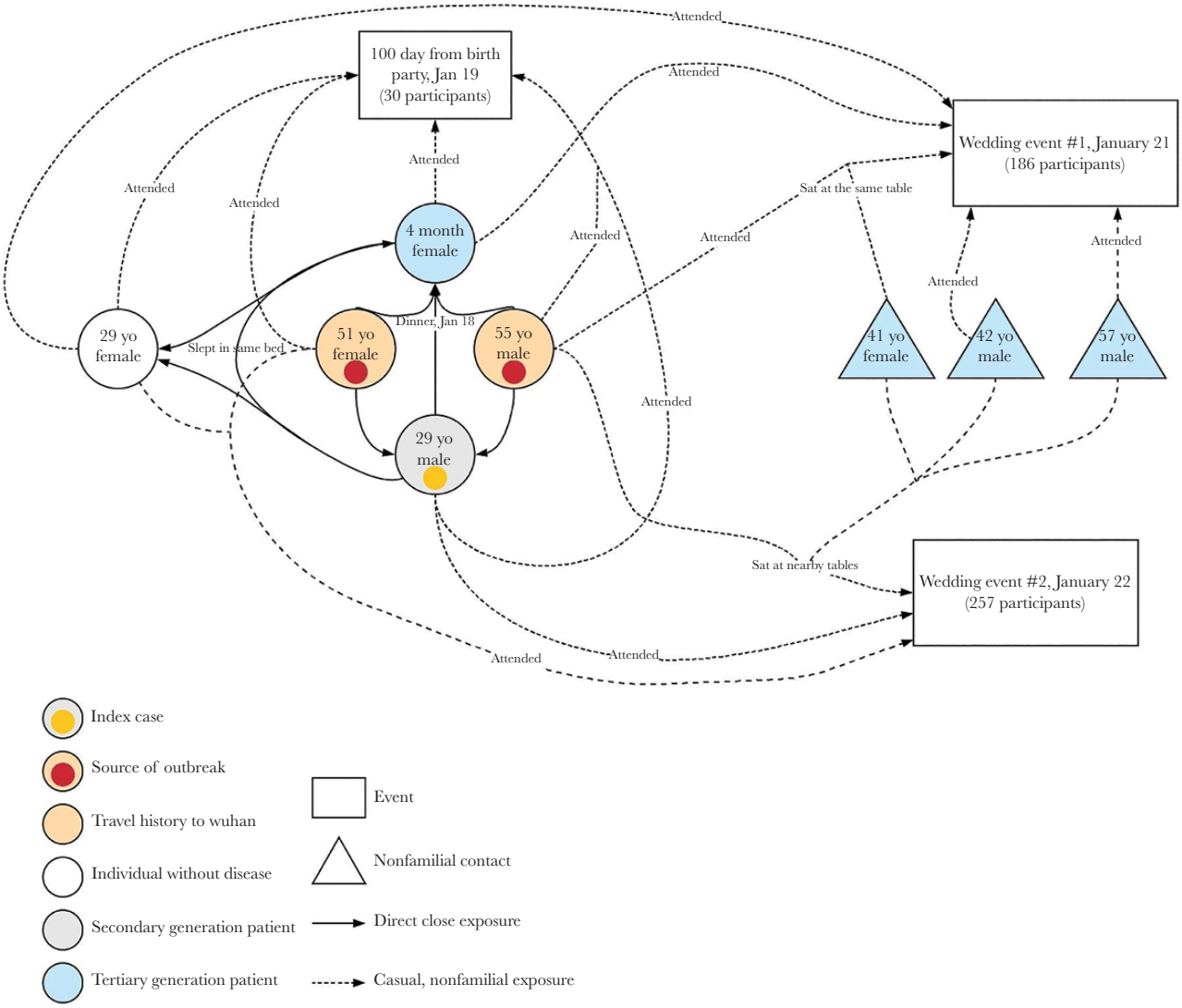

Figure 2. Suspected mode of transmission between Cases 2 and 3 and all related cases and familial close contacts.

female infant patient included fever and diarrhea, but no respiratory symptoms were observed. As reported by the mother of the baby patient, the female infant started to have low-grade fever (37.4℃ in the ear) and diarrhea at 4 AM on January 29, 2020. Shortly after the onset of the symptoms, the baby girl was sent to the Jiaxing01 Hospital for clinical observation and tests. Upon hospital admission, the baby girl had a temperature of 37.5℃, a light runny nose, slight congestion in the throat, and thick breath sounds in both lungs. No wet or dry rales were heard in the lungs. She also had a normal heart rhythm and no cough, shortness of breath, vomiting, diarrhea, bloody urine, or skin rash. A digital radiology scan of the lungs showed increased thickening of the lung texture and reduced transmittance in the lung fields, and no other abnormalities were observed. Meanwhile, blood tests showed normal white blood cell and lymphocyte counts. During the night of hospital admission, the female infant patient tested positive for COVID-19 and was transferred to another hospital for further treatment.

Case 5 was a 42-year-old male. He felt cold on January 26, 2020, 4 days after a wedding that the index case and the source cases attended and had a body temperature of 38℃ on January 27, 2020. He developed fatigue and muscle aches on January 28, 2020. The symptoms continued after he took medications for the common cold, so he voluntarily went to the fever clinic at the Jiaxing03 Hospital, where a CT scan showed ground-glass opacities due to exudate in both lungs and a RT-PCR tested positive for COVID-19.

Case 6 was a 57-year-old male. Due to contact with Case 3, he was quarantined in a designated facility on January 27, 2020. Between January 29 and 31, 2020, the individual had low-grade fever of 37.2–37.4℃ with mental disturbance. On February 1, 2020, the patient started to have fatigue and diarrhea and

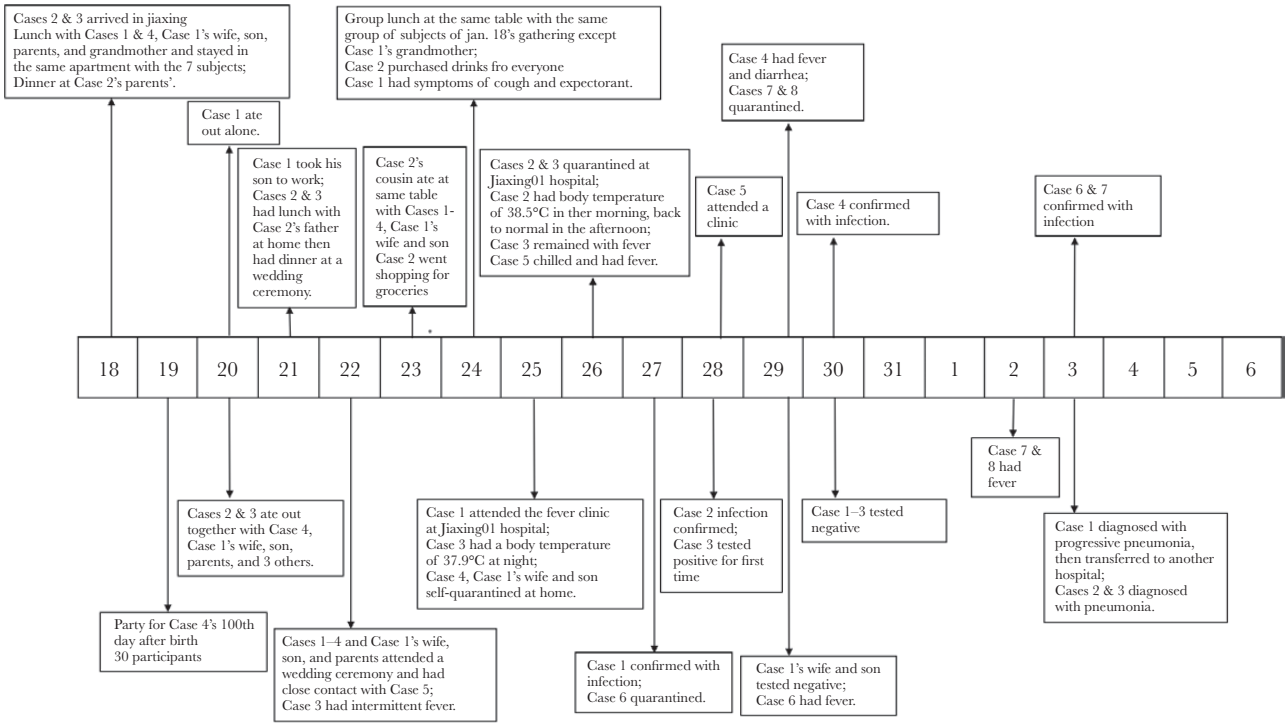

Figure 3. Chronology of gathering activities and disease onsets for Cases 1–8.

was admitted to a hospital, where a CT scan demonstrated inflammatory changes in the middle lobe of his right lung. Two days later on February 3, 2020, the patient was diagnosed with COVID-19 by RT-PCR.

Case 7 was a 41-year-old female. She was quarantined in a designated facility on January 29, 2020 due to contact with Case 3. She started to feel cold and have fever on February 2, 2020 and was admitted to a hospital where a CT scan indicated inflammation in the lower lobe of both lungs. The patient was diagnosed with COVID-19 on February 3, 2020 by RT-PCR.

Suspected Case 8 was a female. She was quarantined in the designated facility on January 29, 2020 due to possible contact with Case 3 and close contact with Case 7. She started to have low-grade fever (37.8℃) on February 2, 2020, but the symptom resolved the next day, and an RT-PCR test for COVID-19 showed a negative result.

Clinical manifestations of the 7 confirmed COVID-19 patients are summarized in Table 1. The patients were aged between 4 months and 57 years, with a median age of 42 years. Four of the 7 COVID-19 patients were males. The most common symptoms were low-grade fever and cough. All patients had fever, and 5 had productive cough. In addition, 3 patients had phlegm, 2 had muscle aches, 2 had diarrhea, and 1 felt sick. Five patients had more than 2 of the symptoms. Blood tests showed that 5 patients had low lymph cell counts, 3 had a lower percentage of lymphocytes, 2 patients had an elevated CRP, and 1 patient had a low white blood cell count. Six of the patients had an abnormal x-ray and/or CT scan of the lungs.

Transmission Dynamics

The index patient's parents-in-law (Cases 2 and 3), referred to as the first-generation cases hereafter, lived in Wuhan for many years. They traveled from Wuhan to Jiaxing on January 18, 2020 to celebrate the Chinese New Year with their daughter's family. Cases 2 and 3 lived with the family of the index patient after arrival in Jiaxing and attended a series of gathering events including a family party and a 2-day wedding during their stay. Some guests at the January 22's wedding also had recently traveled to Wuhan but were never diagnosed with COVID-19. The first-generation cases were not exposed to wild animals and had not eaten in any restaurant during their stay in Wuhan. The mother-in-law bought some vegetables in a local, outdoor food market, and the father-in-law went to collect money from some indoor clothes shops during the 2 weeks before traveling to Jiaxing. In addition, the index patient went to work and had meals with coworkers 3 days before his clinical visit to the Jiaxing 01 Hospital.

Social and family activities that the first-generation cases and the index patient engaged in are detailed according to calendar time in Figure 3. Among the 539 screened individuals who had close contact with the index patient and his parents-in-law during the wedding party and in other public arenas, 3 tested positive and were diagnosed with COVID-19, whereas 1 was a suspected case but did not test positive. Likely routes

Table 1. Characteristics of Confirmed Cases, Clinical Symptoms, and Laboratory Testing Results at Admission

Characteristics	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Relationship to Case 1		Mother-in-law of Case 1	Father-in-law of Case 1	Daughter of Case 1	Attended the Same Wedding With Cases 1–4		
Age, years	29	51	55	0.33	42	57	41
Gender	Male	Female	Male	Female	Male	Male	Female
Occupation	Worker	Business owner	Business owner	Preschool child	Worker	Government Official	Worker
Notable medical history	None	Gastric removal surgery	None	None	None	None	None
Recent travel history to Wuhan	No	Yes	Yes	No	No	No	No
Days between travel from Wuhan/contact with subjects with travel history to Wuhan and symptom onset	6	7	4	11	5–6	7–8	12
Days between travel from Wuhan/contact with subjects with travel history to Wuhan and laboratory confirmation of COVID-19	9	11	11	12	6–7	12–13	12
Days between travel from Wuhan/contact with subjects with travel history to Wuhan and imaging evidence of lung infection	11	NA	NA	NA	6–7	10–11	13
Presenting Symptoms							
First recorded temperature (°C)	36.6	38.5	37.9	37.5	38	37.4	38
Fever, at any time point	+	+	+	+	+	+	+
Cough	+	+	+	–	+	+	–
Expectorant	+	–	+	–	–	+	–
Shortness of breath	–	–	–	–	–	–	–
Muscle soreness	–	–	+	–	+	–	–
Unconsciousness	–	–	–	–	–	–	–
Headache	–	–	+	–	–	–	–
Sore throat	–	–	–	–	–	–	–
Rhinorrhea	–	–	–	–	–	–	–
Chest pain	–	–	–	–	–	–	–
Diarrhea	–	–	–	+	–	+	–
Nausea and vomiting	–	–	+	–	–	–	–
Multiple symptoms appear at the same time	+	–	+	+	+	+	–
Fever, cough, shortness of breath	–	–	–	–	–	–	–
Admission Laboratory Testing							
White blood cell count (10^9/L)	7.77	1.25↓	NA	7.49	5.4	5.4	8.9
Neutrophil count (10^9/L)	NA	NA	1.7	NA	NA	NA	NA
Lymphocyte count (10^9/L)	0.8↓	0.6↓	0.7↓	2.98	7.6	1.0↓	0.7↓
Neutrophil cell (%)	80.5↑	NA	NA	NA	55	66.8	84
Lymphocyte cell (%)	9.7↓	NA	NA	NA	29.3	17.7↓	7.6↓
C-reactive protein (mg/L)	3.6	NA	10.28	NA	NA	23.5↑	2.1

Abbreviations: COVID-19, novel coronavirus disease 2019; NA, not applicable.

of transmission between Cases 2 and 3 and all other cases are shown in Figure 2. All confirmed cases had contact with the father-in-law (Case 3) who had fever but tested negative in the first RT-PCR test and eventually was confirmed to have COVID-19 in a second test by the Zhejiang Provincial CDC. Cases 5–7 all attended the wedding. During the wedding, Case 6 ate at the same table as Case 3, chatted at close distance, and they picked up guests together. Case 7 ate at a table next to Case 3 on the first day of the wedding, and they stayed in the same room during the ceremony on the second day. Case 7's daughter was a suspected case (Case 8). She also attended the weddings on both days and was quarantined with Case 7 in the same home but different rooms. On February 2, 2020, Case 8 had temporary fever (body temperature was 37.8°C), but RT-PCR test on the same day showed negative result.

Among the 7 immediate members of the index patient's family, only the index patient and his 4-month-old daughter were affected by the COVID-19. The 4-month-old infant daughter slept with the index patient and his wife in the same bed. After being diagnosed with COVID-19, the index patient's wife, son, and daughter were strictly quarantined in their home. The index patient's son lived in the same room with the index patient's parents-in-law; however, the grandson was not affected.

Table 2. Secondary Attack Rates for Reported Social Events

Event	Date	Maximum Number of Potential Infectious Present[a]	Susceptible Present	Upper Bound of Possible New Infections	Upper Bound for Secondary Attack Rate (%)
Lunch	January 18	2	7	2	2/7 = 29%
Birthday party	January 19	4[b]	30	0[c]	0/30 = 0%
Wedding party day 1	January 21	4[b]	186	3[c]	3/186 = 2%
Wedding party day 2	January 22	4[b]	257	3[c]	3/257 = 1%
Lunch	January 24	4[b]	4	0	0/4 = 0%

[a]Assumes that both Cases 2 and 3 were infected and potentially infectious throughout this period, and Cases 1 and 4 were infected and potentially infectious by January 21.

[b]Includes the 4-month-old.

[c]Assumes that Cases 1 and 4 did not get infected during those events.

During the outbreak cluster, 3 larger events occurred, namely, 2 wedding parties on consecutive days, as well as a birthday party for the 4-month-old. Table 2 summarizes these events and indicates possible new infections for each event. Transmission did occur during the wedding party, and there was none reported during the birthday party. Thus, across all events involving casual contacts, the secondary attack rate (SAR) was 0.6% (3 of 473). In addition, 2 lunches with different family members were recorded. It is possible that transmission to Cases 1 and 4 occurred during the first lunch; however, it is more likely that it occurred during other close contact. No transmission was recorded during the second lunch. Of note, several close family members attended all these events and had further interactions with several of the cases and nevertheless did not get infected. The overall SAR estimate among close contacts is 29% (2 of 7).

Conclusion of Outbreak

All reported cases in this study were mild and have been cured and discharged from hospitals. Our epidemiological investigation suggests that the most likely transmission route from the familial cluster to the other cases is through contacts and shared spaces at the same wedding ceremonies on January 21 and 22, 2020 attended by all the cases.

DISCUSSION

We found that there was strong evidence of COVID-19 transmission to contacts outside of the immediate family members. Of 539 individuals with close contact with the index patient and his parents-in-law, 4 tested positive for disease, an attack rate of approximately 0.7%. Based on detailed contact information, we estimate the SAR among close contacts to be 29% (2 of 7), and for the casual contacts attending 3 events (2 wedding events and 1 birth party) we estimate the SAR to be 0.6% (3 of 473). The large difference between the SAR in casual and close contacts is important and similar to a recent report from the United States, which would suggest that COVID-19 is possibly transmitted more via a droplet mechanism rather than airborne [11]. As COVID-19 prevalence continues to increase, the attack rate from casual contact between individuals with COVID-19 and susceptible individuals is critical to understanding further spread of the epidemic. Despite this, attacks rates among casual contacts have not been well described in the literature. The incubation period of our case cluster is 4–12 days with a median incubation period of 7 days, which is longer than those reported from a nationwide study in China (4.0 days [9]).

The current study documented evidence that COVID-19 can be transmitted through casual contact with a source patient at social events. In Wuhan, where the first outbreak of COVID-19 occurred, community spread of the disease is likely given the large number of infections occurring in a short time span. Our study findings provide further evidence that, even in areas of fewer cases such as Zhejiang province, COVID-19 can spread through casual contacts at social gatherings. With existing evidence that transmission may happen in the incubation period of source patients [4, 12], travelers from outbreak regions should avoid attending social or family events for at least 2 weeks. Organizers of large gatherings (eg, conventions, marathons, etc) may need to consider the transmission potential of COVID-19 in such settings and the amount and type of social interaction that takes place at such events. Our findings suggest that casual contact in such settings is not negligible.

Similar to previous findings from other studies [2, 9, 13, 14], common symptoms of our cases include fever, cough, sputum, and fatigue [3, 9], and common laboratory findings include decreased white blood cell count, lower lymphocyte count and percentage, and elevated CRP. Sputum production with coughing were reported in 3 cases. In addition, 3 patients had gastrointestinal symptoms and 2 patients experienced diarrhea, despite a recent nationwide study suggesting that diarrhea was uncommon among confirmed COVID-19 cases [9]. Case 4 was a 4-month-old infant with fever and diarrhea as the main symptoms, suggesting that a very young child may have atypical symptoms after contracting the new coronavirus. Case reports of young children infected with COVID-19 at this early stage of development are rare, and therefore we documented detailed information on clinical features and progressions over the course of disease development for this subject. In this cluster outbreak, the early symptoms of an infection did not necessarily include fever, but rather cough, expectoration, fatigue, and others that raises lower alert levels.

This observation is consistent with a recent nationwide study of 1099 COVID-19 patients [9].

With the combined evidence of our epidemiological investigation, the patients' clinical symptoms, and laboratory test results, we believe that the most likely sources of transmission for this cluster can be traced back to Cases 2 and 3, who had recent travel histories to Wuhan. In the familial cluster (Cases 1–4), our current knowledge about the incubation and transmission dynamics of COVID-19 [1] suggests 4 possible routes of transmission within the family: (1) Cases 1, 2, and 4 were second-generation cases of Case 3's; (2) Cases 1 and 2 were second-generation cases of Case 3, and Case 4 was a possible third-generation case; (3) both Cases 2 and 3 were first-generation cases, and Cases 1 and 4 were second-generation cases; (4) both Cases 2 and 3 were first-generation cases, whereas Case 1 was a second-generation case and Case 4 was a third-generation case, respectively.

Several limitations of the current investigation are noted. There were other participants with recent travel histories to Wuhan at the wedding on January 22, 2020, so other routes of transmissions to Cases 5–7 cannot be completely ruled out. However, those participants were not in close contact to Cases 4–7 at the wedding, and none of them tested positive for COVID-19. Because Cases 5 and 6 and Case 3 were in close contact, and Case 7's seat was very close to Case 3's at the wedding, and given that there are currently no other confirmed cases from the participants of the wedding on January 22, 2020, the acquired SARS-CoV-2 infections of Cases 5–7 is highly likely to be transmitted by Case 3. In addition, current diagnosis of SARS-CoV-2 infection mainly relies on the available RT-PCR assay [9]. Given the limited time to develop such testing kits and issues related to quality control in production, false-negative results were expected and have been reported in practice [12, 15–17]. In our study, Cases 1–3 had repeated tests showing SARS-CoV-2 negative and normal body temperatures in the early stage of disease development. They were eventually confirmed with RT-PCR assays after developing apparent disease symptoms such as cough and fever. Meanwhile, there have been reported cases of patients recovered from COVID-19 who tested positive a second time 5–13 days after being discharged from the hospital [18]. As such, there is an urgent need to evaluate the sensitivities of current available COVID-19 testing kits and to develop new tests with better accuracy.

CONCLUSIONS

In conclusion, our investigation of a cluster of infections associated with COVID-19 demonstrates that person-to-person transmission among casual contacts can and does occur at social gatherings with congregation of large groups of susceptible individuals. More importantly, from an individual perspective, the attack rate from casual contact was much lower than through close contact.

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References

1. Li Q, Guan X, Wu P, et al. Early transmission dynamics in Wuhan, China, of novel coronavirus-infected pneumonia. N Engl J Med **2020**; 382:1199–207.
2. Chen N, Zhou M, Dong X, et al. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. Lancet **2020**; 395:507–13.
3. Chan JF-W, Yuan S, Kok K-H, et al. A familial cluster of pneumonia associated with the 2019 novel coronavirus indicating person-to-person transmission: a study of a family cluster. Lancet **2020**; 395:514–23.
4. Yu P, Zhu J, Zhang Z, Han Y, Huang L. A familial cluster of infection associated with the 2019 novel coronavirus indicating potential person-to-person transmission during the incubation period. J Infect Dis **2020**; 221:1757–61.
5. Phan LT, Nguyen TV, Luong QC, et al. Importation and human-to-human transmission of a novel coronavirus in Vietnam. N Engl J Med **2020**; 382:872–4.
6. Liu Y, Eggo RM, Kucharski AJ. Secondary attack rate and superspreading events for SARS-CoV-2. Lancet **2020**; 395:e47.
7. Hodcroft EB. Preliminary case report on the SARS-CoV-2 cluster in the UK, France, and Spain. Swiss Medical Weekly **2020**; 150(9-10). doi:10.4414/smw.2020.20212.
8. Liu J, Liao X, Qian S, et al. Community transmission of severe acute respiratory syndrome coronavirus 2, Shenzhen, China, 2020. Emerg Infect Dis **2020**; 26(6):1320–3.
9. Guan W-J, Ni Z-Y, Hu Y, et al. Clinical characteristics of coronavirus disease 2019 in China. N Engl J Med **2020**; 382:1708–20.
10. R Core Team: A Language and Environment for Statistical Computing [computer program]. **2013**.
11. Burke RM, Midgley CM, Dratch A, et al. Active monitoring of persons exposed to patients with confirmed COVID-19 — United States, January–February 2020. MMWR Morb Mortal Wkly Rep **2020**; 69:245–6.
12. Bai Y, Yao L, Wei T, et al. Presumed asymptomatic carrier transmission of COVID-19. JAMA **2020**; 323:1406–7.
13. Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet **2020**; 395:497–506.
14. Hui DS, I Azhar E, Madani TA, et al. The continuing 2019-nCoV epidemic threat of novel coronaviruses to global health—The latest 2019 novel coronavirus outbreak in Wuhan, China. Int J Infect Dis **2020**; 91:264–6.
15. Ai T, Yang Z, Hou H, et al. Correlation of chest CT and RT-PCR testing in coronavirus disease 2019 (COVID-19) in China: a report of 1014 cases. Radiology **2020**:200642.
16. Lee EY, Ng M-Y, Khong P-L. COVID-19 pneumonia: what has CT taught us? Lancet Infect Dis **2020**; 20:384–5.
17. Kim S, Kim D-M, Lee B. Insufficient Sensitivity of RNA Dependent RNA Polymerase Gene of SARS-CoV-2 Viral Genome as Confirmatory Test using Korean COVID-19 Cases. **2020**. doi:10.20944/preprints202002.0424.v1.
18. Lan L, Xu D, Ye G, et al. Positive RT-PCR test results in patients recovered from COVID-19. JAMA **2020**; 323:1502–3.