

Transmission of SARS-CoV-2 in Public Transportation Vehicles: A Case Study in Hunan Province, China

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Abstract

Here we report a case study of a SARS-CoV-2 outbreak event during bus trips of an index patient in Hunan Province, China. This retrospective investigation suggests potential airborne transmission of SARS-CoV-2 and the possibility of superspreading events in certain close contact and closed space settings, which should be taken in to account when control strategies are planned.

Key words: SARS-CoV-2; COVID-19; Probable airborne transmission; Vehicles

Text

The pandemic of coronavirus disease 2019 (COVID-19) is imposing a serious threat to global public health and economy. While WHO and the U.S. CDC stated that direct contact with respiratory droplets from sneezing and coughing patients or contaminated fomites is the predominant transmission route of SARS-CoV-2, the causative pathogen for COVID-19, there have been speculations about the possibility of aerosol transmission and its contribution to the pandemic^{1,2}. Aerosols containing viable SARS-CoV-2 particles have been detected in hospitals^{3,4}, and has been shown to last for three hours in laboratory conditions⁵. In addition, there have been several studies reporting transmission events from asymptotically infected individuals or from COVID-19 patients during their presymptomatic incubation period, further indicating the possibility of aerosol transmission^{6,7}. Here we report a contact-tracing study on a COVID-19 outbreak event involving public transportation in Hunan Province, China. In this outbreak, we identified 10 lab-confirmed infections directly associated with the exposure to a single COVID-19 patient during bus trips. This case study adds useful information to our understanding of the transmission route of SARS-CoV-2.

The primary case (Patient A), who worked at Place I, had symptom onset on January 22 and was tested positive for SARS-CoV-2 on January 29. According to a retrospective investigation, five and three days prior to his onset of symptoms, respectively, he had meals and work-related contact with his colleague (infection source) who had onset on January 14 and was tested positive on January 16, 2020. On January 22, 2020, Patient A travelled without wearing face mask from Place I to Place III via public transportation, with a transfer at Place II. The first ride on a tour coach took 2.5 hours, and the second ride on a minibus took about 1 hour. After he was confirmed to be a COVID-19 case, a total of 243 close contacts of patient A and subsequently identified infections were traced and monitored.

METHODS

According to the guidelines of the New Coronavirus Pneumonia Prevention and Control Program (4th edition) published by National Health Commission of China⁸, nasopharyngeal swabs were collected from suspected cases, including patient A and contacts with subsequent illness onsets, and all traced close contacts of confirmed cases. The specimens underwent a real-time reverse transcription polymerase chain reaction (RT-PCR) assay⁹. In addition, an epidemiological survey was administered on each suspected case to inquire about his or her travel history and close contacts. Details regarding the seating arrangement on the buses and loading and unloading stops of all passengers were obtained from the public transportation authority.

RESULTS

A total of 243 individuals, in addition to patient A, were investigated for the cluster of COVID-19 cases who were epidemiologically linked to the bus trips of patient A on January 22, 2020. Of these individuals, 12 were tested positive and confirmed to be COVID-19 cases. The remaining test-negative 231 individuals returned home after a 14-day quarantine period. The detailed timeline of illness onsets for all cases is presented in Figure 1A.

The tour coach was 11.3 meters long and 2.5 meters wide with 49 seats, fully occupied with all windows closed and the ventilation system on during the 2.5-hour trip. Among the 49 passengers (including driver) who shared the ride with Patient A (Figure 1B), eight were tested positive and eight developed symptoms (Patient B with onset on January 23, Patients C, D, and E on January 26, Patients F and G on January 28, and Patient H on February 4), with a single asymptomatic infection (Patient I). Patient C was finally excluded because he/she was tested negative of SARS-CoV-2 virus by RT-PCR for three times at different days and negative of antibody including IgM and IgG. Patient A sat at the second rear row, and the other nine infected passengers were distributed over the middle and rear rows. The nearest infectee was Patient E (with onset four days later) who sat right behind Patient A, about 1 meter away. The furthest infectees were patient D and patient G who sit seven rows (about 4.5 meters) away from patient A and became ill four and six days later, respectively. The retrospective survey indicated that patients A and G got on and off through different doors of the bus and had no direct contact with each other during the whole trip. The ventilation system and possible directions of airflow in the bus were shown in Figure 1B.

After arrival at place II, the tour coach parked for 30 minutes, without any disinfection, and then loaded another group of passengers and returned to Place I. Among the 49 passengers (excluding driver) on the return trip, patient J, who sit in close proximity to the seat that Patient A had occupied during the last trip, had symptom onset on January 24.

During the trip of Patient A from Place II to Place III on the minibus (Figure 1C), two (Patients K and L) out of 12 passengers (including driver) were diagnosed with COVID-19 with symptom onsets on January 24 and 31, respectively. The minibus is about 5.5 meters long and 2.5 meters wide with 18 seats. All windows were closed during the one-hour trip. Patient A was seated one row (about 1.5 meters) away from patient L and three rows (about 4.5 meters) away from patient K. The ventilation system and possible airflow directions in the minibus were shown in Figure 1C.

None of these 10 secondary cases wore face masks during the rides. We found two tertiary cases, Patients M and N, who are cousins of the secondary cases Patients B and K, respectively. Patients M and N each had lived together with their cousins since January 22, and developed symptoms on January 31. None of these 12 secondary and tertiary cases had traveled to Wuhan City, the COVID-19 epi-center of China, or had been exposed to other COVID-19 patients in the two weeks prior to their symptom onset. The provincial surveillance data indicate there were limited locally infected cases in Hunan Province before January 22, 2020; in particular, only seven, two, and zero locally infected cases were reported before January 22 in the cities or counties where Places I, II, and III are located, respectively (Figure 2). According to the epidemiological surveys on all the secondary and tertiary cases, none of them had travel history to Wuhan or nearby cities, and no known infections were reported in their work places or communities during the 14 days before January 22, 2020. The median incubation period among the secondary cases was 4 (range: 1, 13) days. Excluding patient J and focusing only on the two bus trips of patient A, we estimated the secondary attack rate (SAR) during an exposure period of up to 2.5 hours on a bus to be $9/(48+12)=15.00\%$ (95% CI: 6.00-24.00%).

DISCUSSION

This outbreak on public transportation vehicles highlighted the efficient transmission of SARS-CoV-2 in crowded and closed settings. According to the WHO, the main transmission routes of COVID-19 appeared to be respiratory droplets or direct contact with fomites⁸. Transmission via droplets is usually confined to distances within 2 meters; however, the majority of secondary cases were seated more than 2 meters away from patient A. Some cases might have been infected by touching fomites. On the other hand, this transmission route was unlikely to explain every secondary case, e.g., patient G was never physically close to patient A or where he passed by during the whole trip. The closed windows with running ventilation on the buses could have created an ideal environment for aerosol transmission¹⁰,. Aerosol transmission occurs when microorganisms are contained in droplet nuclei of a size $< 5-10 \mu\text{m}$ which can remain suspended in the air and thus travel relatively far^{11,12}. On the tour coach, the ventilation inlets were aligned above windows on both sides and the exhaust fan was in the front, possibly creating an airflow carrying aerosols containing the viral particles from the rear to the middle and front of the vehicle. Consequently, aerosol transmission cannot be ruled out.

Several limitations are inherent in our study: (1) we could not verify transmission via fomites as no environmental samples were collected; (2) the SAR was likely over-estimated as it is solely based on a single large cluster; (3) there might be recalling bias because the information (including the seat number) was collected retrospectively; (4) no viral genetic sequence data were available from these cases to prove linkage; and (5) some of the secondary and tertiary cases could have been exposed to unknown infections, especially asymptomatic ones, before or after the bus trips. Given the potential for fomites and aerosol transmission of SARS-CoV-2, we recommend timely disinfection of public transportation vehicles and an “open window” policy whenever possible. It is also crucial for all individuals, regardless of having respiratory symptoms or not, to wear face masks and to maintain hand hygiene when they use public transportation.

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Potential conflicts of interest

The authors declare that they have no competing interests.

Patient Consent Statement

This effort of outbreak control and investigation was part of CDC's routine responsibility in Hunan Province; therefore, institutional review and informed consent were waived by Medical Ethics Committee of Hunan Provincial Center for Disease Control and Prevention on the following grounds: (1) only broad information was collected with no identifying patient information; (2) neither medical intervention nor biological samples were involved; (3) study procedures and results would not affect clinical management of patients in any form.

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Figure legends

Figure 1. The transmission chain of SARS-CoV-2 and the seat arrangement of passengers in public transportation vehicles. A: The transmission chain of a COVID-19 outbreak on buses in Hunan Province, China. Arrows indicate transmission links and directions; B: The seat arrangement of passengers who shared a ride with the index patient on a tour coach. Passengers are colored by disease status: index case (red), secondary cases (orange), secondary asymptomatic infection (yellow) and uninfected passengers (blue). Arrows indicate the paths of boarding and debussing. C: The seat arrangement of passengers who shared a ride with the index patient on a minibus. Passengers are colored by disease and facemask-wearing status: index case (red), secondary cases (orange), and uninfected passengers (green if wearing a mask or blue if not).

Figure 2. Epidemic curves of COVID-19 in Hunan Province and its three sub-regions related to this study. Cases were classified as imported symptomatic cases, imported asymptomatic cases, locally infected symptomatic cases, and locally infected asymptomatic cases. Epidemic curves of COVID-19 are shown for A: Hunan Province; B: the city where Place I is located; C: the city where Place II is located; and D: the county where Place III is located

Figure 1

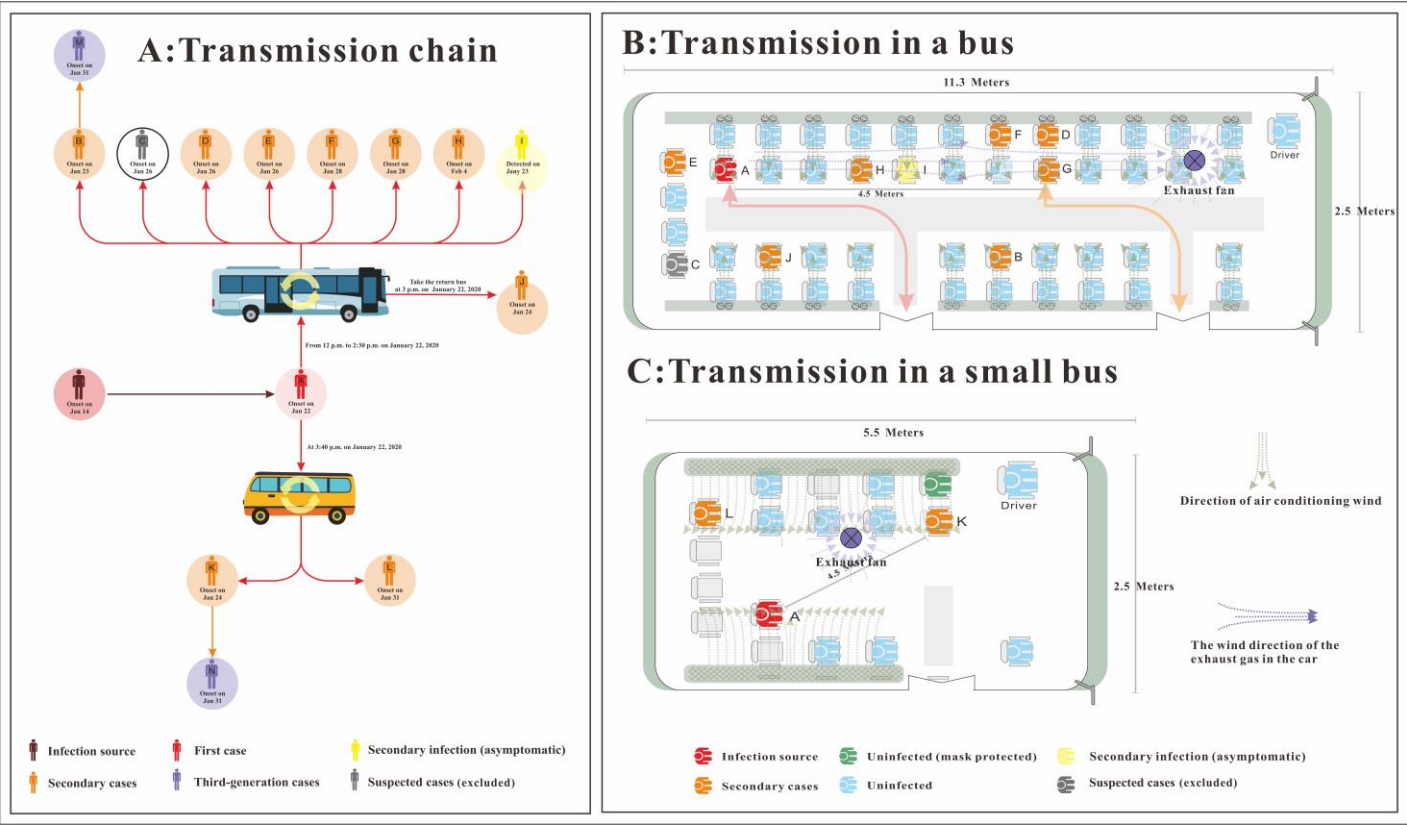


Figure 2

