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Short Communication

# Investigation of a COVID-19 cluster involving vertical transmission in a residential building, Taiwan, 2021



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Tracer-gas experiments;  
COVID-19;  
Exhaust systems

**Abstract** We investigated a COVID-19 cluster involved seven case-patients lived in a high-rise building in September 2021. We used a simplified tracer-gas experiment and virus sequencing to establish the link between case-patients. Vertical transmission among vertically aligned apartments on different floors in a building was the most likely route of transmission. Copyright © 2023, Taiwan Society of Microbiology. Published by Elsevier Taiwan LLC. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

## Introduction

It is now widely recognized that SARS-CoV-2 can be transmitted through the inhalation of virus-laden aerosols<sup>1,2</sup>. There have been reports of long-range aerosol transmission occurring in various indoor settings, including quarantine hotels.<sup>3</sup> Previous reports in different countries have also

revealed aerosol transmission between vertically aligned apartments on different floors in a building,<sup>4–6</sup> which has been known as vertical transmission. However, the impact of building structures and exhaust systems on such transmission in Taiwan has not been well studied.

On September 7, 2021, a COVID-19 cluster within a residential building in northern Taiwan was reported to the Taiwan Centers for Disease Control (TCDC). All the infected individuals lived in apartments on different floors of the building, and the apartments were aligned vertically. The TCDC launched an investigation to identify the infection source and possible transmission routes.

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## Methods

The public health sector set up a COVID-19 testing station in front of the building for four days and took samples with nasopharyngeal swabs from all residents and visitors. For contact tracing, all residents of the building who had been living there for the 14 days prior to the investigation were considered close contacts. All residents of the building underwent an RT-PCR test at the beginning of the investigation, and an additional test at the end of their 14-day quarantine period. On October 12, 2021, we inspected the bathroom exhaust system of the building by directly examining the involved apartments on the 10th and 12th floors. We also interviewed the residents of the two apartments. Tracer-gas experiments were conducted to assess the interconnections between the two apartments and to determine if the indicator could reach the roof. We measured total volatile organic compounds (TVOCs) by means of an air quality monitor (ToxiRAE PRO PID PGM-1800, RAE Systems, San Jose, CA, USA) and used acetone aerosol as the indicator because the monitor can detect this TVOC. Acetone aerosol was released in the involved apartment on the 10th floor, and measurements were taken on the 12th floor and at the outlet of the exhaust pipeline on the rooftop. The virus sequences of specimens were collected and analyzed from five case-patients (See [Appendix - Laboratory investigation for details](#)).

## Results

Seven COVID-19 case-patients were identified from the same vertical line of apartments (See [Appendix - Case investigation & Table](#)). Six of the case-patients were residents, and the seventh was a decorator who had worked in one of the involved apartments ([Fig. 1](#)). At the beginning of investigation, a total of 813 people tested negative. The epidemiological investigation did not identify any infection source outside the apartments. All patients from different apartments denied having any interpersonal contact with each other. On September 8, 2021, a total of 364 residents from 128 households were evacuated to designated quarantine facilities for 14-day quarantine. All tested negative at the end of quarantine.

The residential building was built in 1988. It has 26 floors, with 5 apartments on each floor, for a total of 128 apartments. The building has two elevators shared by all the apartments. The elevator hall has two emergency exits on each floor, each equipped with an escape ladder, but has no windows ([Fig. 1](#)). In the building, a natural ventilation shaft is located along each vertical line from the bottom to the rooftop. Each shaft is connected to the apartments within the same vertical line, through the exhaust vents in the bathrooms ([Fig. 1](#)). The bathrooms of the apartments along the involved vertical line do not have windows. The bathroom of the 10th floor has an exhaust fan controlled manually and is not connected to the ceiling lamp. This type of exhaust fan does not have a backstop damper. In contrast, the 12th floor bathroom hadn't installed an exhaust fan yet because the apartment was undergoing renovations.

Before the tracer-gas experiment, the concentration of TVOCs was undetectable ([Table 1](#)). However, after acetone was released from the bathroom exhaust fan of the involved apartment on the 10th floor, TVOCs were detected in the involved apartment on the 12th floor within 20 s, but they were not detected on the rooftop after a wait of more than 5 min. The results of virus sequences were classified as the Delta variant (B.1.617.2 lineage), which shared unique single-nucleotide polymorphisms, indicating that these cases were infected with a common source (See [Appendix - Figure](#)).

## Discussion

Based on our findings, we concluded that SARS-CoV-2 Delta variant transmission occurred in vertically aligned apartments in this residential building. The building has 2 elevators for all residents but case-patients were only identified among residents who lived along one vertical exhausted pipeline, which is unlikely to happen by chance. Vertical transmission through the shared exhaust pipeline across floors was the most likely route of transmission. At the time of this investigation, because strict measures were in place for entry screening, quarantine, and isolation, there was no active community transmission in Taiwan (See [Appendix - Epidemiology backgrounds of COVID-19 in Taiwan](#)). We infer that the index case-patient in this cluster was the patient who had recently travelled abroad (See [Appendix - Case investigation](#)). The investigation provides evidence of the long-distance transmission of SARS-CoV-2 across several floors.

Previous studies had used tracer-gas methods to simulate the process of potential transmission through air in a quarantine hotel and in the Amoy Garden.<sup>3,7</sup> Our detection of the organics quickly from the 10th floor to the 12th floor but not on the rooftop suggests that there might be other leakages along the vertical pipeline and interconnection of apartments through a communal vertical exhaust pipeline.

According to the analyses in a study by Zhao et al., the characteristics of COVID-19 vertical transmission within residential buildings showed that such clusters were more likely to occur in old high-rises.<sup>5</sup> Data were collected from 19 clusters with involved buildings that were completed between 1964 and 2000, and the median number of residential floors was 24 (ranging from 10 to 41). These findings are consistent with this cluster we investigated, within a 26-floor residential building completed in 1988. A COVID-19 cluster in residential buildings had also occurred in March 2022.<sup>8</sup> However, the sudden increase of patients infected with Omicron variants made detailed contact tracing and investigation not possible. Therefore, the number of similar clusters could be underestimated.

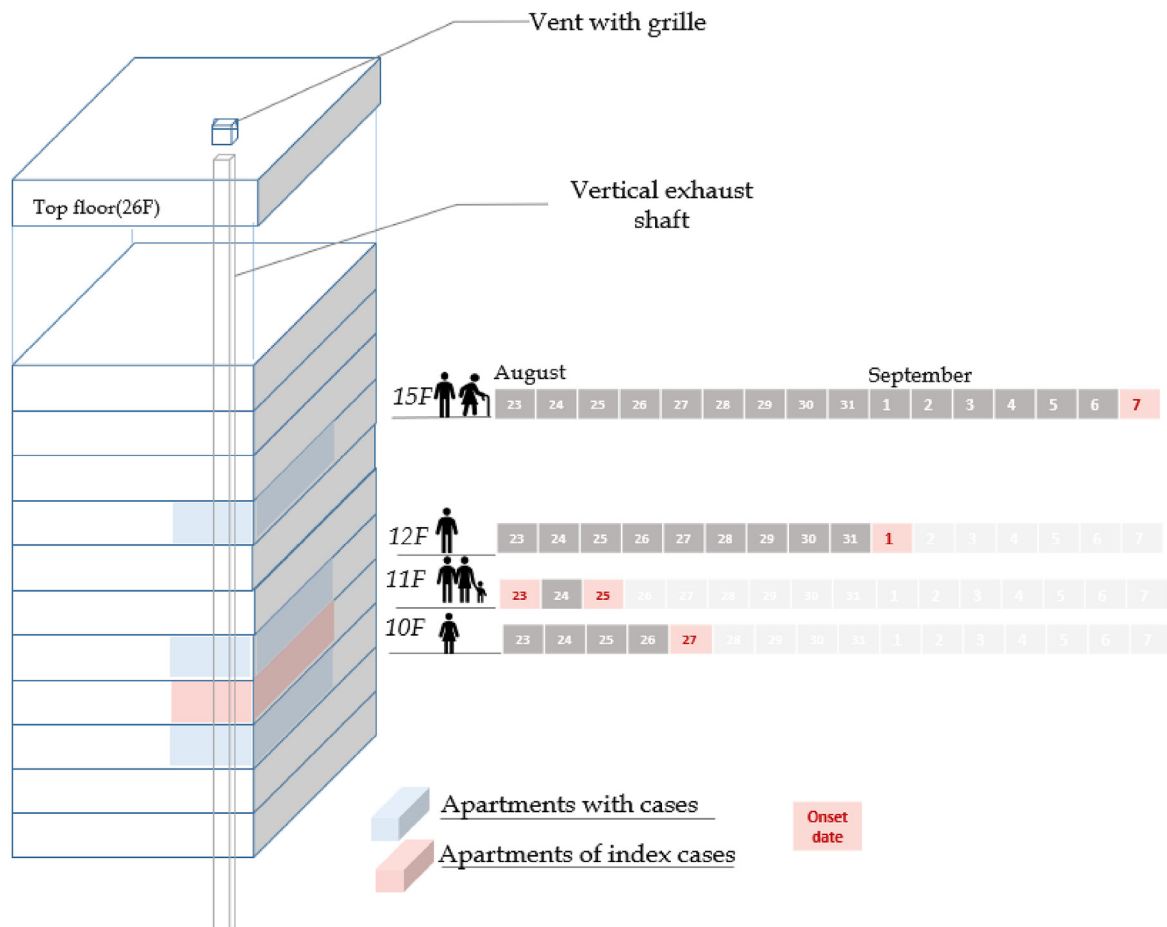
In Taiwan, the general design of bathroom exhaust systems in older buildings includes one communal pipe room that collects exhaust from each floor and opens onto the roof. The shared ventilation pipelines jointly discharge exhaust and moisture from bathrooms. Most households set exhaust fans in their bathrooms. Exhaust fans push the

air most upwards. In this investigation, we observed that most case-patients lived on floors above the index case-patients, which is consistent with a previous study that showed such infections occurred mostly among upstairs neighbors.<sup>5</sup> Sometimes, downstairs neighbors were also involved. The manual-controlled fan found on the 10th floor is a common feature in regular households. However, some people aren't accustomed to turning it on when using the toilet, as was the case on the 10th floor. The situation was similar on the 12th floor, which lacked an exhaust fan. When multiple fans in the same pipeline do not operate simultaneously, it can lead to variations in air pressure and result in airflow moving from the functioning fan to the non-functioning one nearby, upwards, and downwards. The households without fan or with fan but not functioning are more vulnerable to the exhaust air produced by neighbors.

Air quality is a common problem in residential buildings. Some countries have regulations in place to prevent contaminated air from spreading to neighboring units. In Spain, it has been mandatory to install an electrical exhaust fan on top of the vent since 2006.<sup>9</sup> In South Korea, it has been mandatory to install an automatic backstop damper on the exhaust vents within a household or an exclusive exhaust duct to prevent odors from flowing to other households since 2015.<sup>10</sup> However, in Taiwan, devices that prevent air recircuit are not required. Therefore, contaminated odors shared from the neighboring floors are still a common issue and pose a potential threat of SARS-CoV2 transmission.

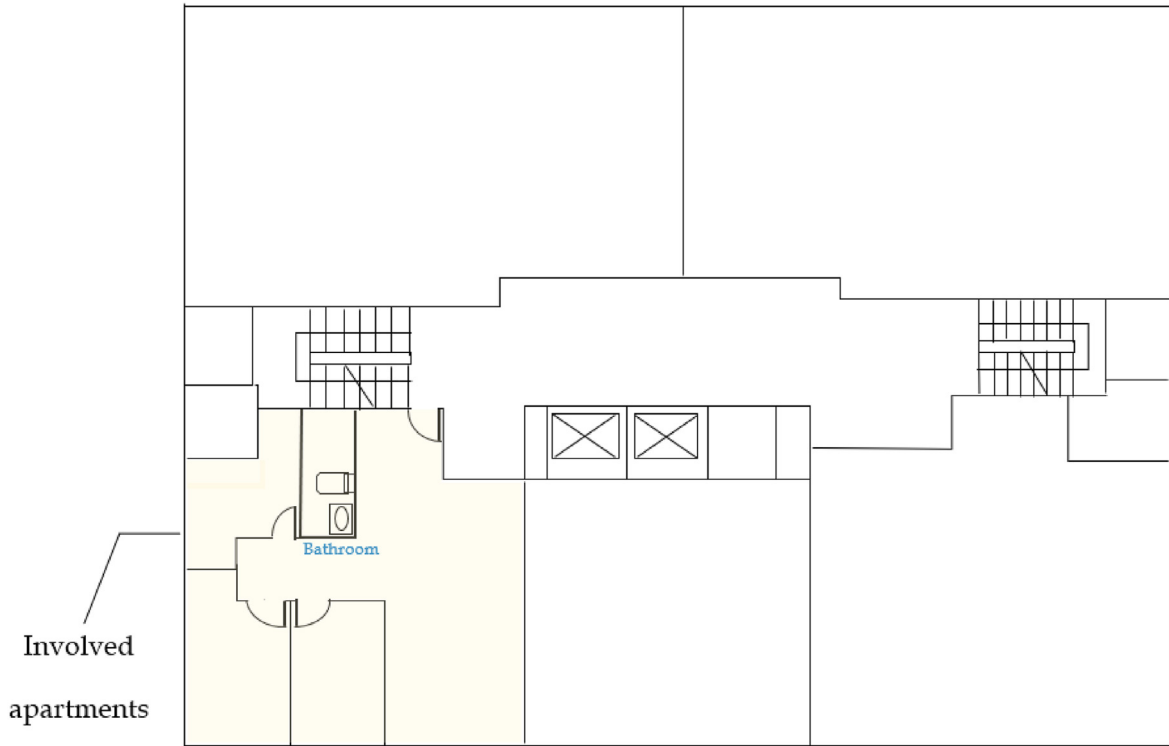
This investigation had several limitations. First, we did not investigate the involved apartments on the 11th and 15th floors, so we were unable to know the type of bathroom exhaust fans they had or how they were used. Second, we didn't conduct serology tests among residents to

A.



**Figure 1.** A. Diagram of vertical transmission of SARS-CoV-2 in the residential building. B. Layout of the involved residential building. C. Picture of house-shape vent with iron grille covering the exhaust pipeline outlets on the rooftop. There are five vents, one for each vertical line of the apartments.

B.



C.



Figure 1. (continued).

exclude the possibility of an occult infection source. Additionally, we did not inspect or evaluate other pathways across different floors, such as drainage pipes, flues, or ducts, which could also potentially facilitate disease transmission.

The risk of COVID-19 spreading vertically within high-rise buildings is under-recognized. To further reduce the risk of vertical transmission, we recommend that residents of old high-rise buildings better keep exhaust fan turn-on and the owners/managers improve the building exhaust systems.

**Table 1** The concentration of total volatile organic compounds (TVOCs) measured with tracer-gas detection<sup>a</sup> on specific floors.

Detection Location	Baseline TVOC (ppm)	Read time from release in the 10th floor bathroom	TVOC (ppm)
Bathroom of 12th floor	0.0	20 s	26
Opening of the bathroom exhaust pipeline on rooftop (27th floor)	0.0	>5 min	0.0

<sup>a</sup> Acetone aerosol was used as the indicator for tracer-gas detection of TVOCs.

## Funding source

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## Ethical approval

Because this was an outbreak investigation of a national notifiable disease, the study was exempt from institutional review board review. However, the records review process did follow the medical records confidentiality policy.

## Declaration of competing interest

All authors report no conflicts.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jmii.2023.08.009>.