SARS-CoV-2 delta AY.1 variant cluster in an accommodation facility for COVID-19: Research study

Takayuki Ohishi (✉ endlessjealousy@gmail.com)

Saiseikai Yokohamashi Tobu Hospital

Takuya Yamagishi

Saiseikai Yokohamashi Tobu Hospital

Hitomi Kurosu

Saiseikai Yokohamashi Tobu Hospital

Hideaki Kato

Yokohama City University Hospital

Yoko Takayama

Kitasato University School of Medicine

Hideaki Anan

Kanagawa prefectural government

Hiroyuki Kunishima

Kanagawa prefectural government

Research Article

Keywords: SARS-CoV-2, cluster, delta variant, AY.1, air ventilation

Posted Date: January 13th, 2022

DOI: <https://doi.org/10.21203/rs.3.rs-1233896/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License. [Read Full License](#)

Abstract

Background

This is a case report on a cluster infection of novel severe acute respiratory syndrome coronavirus 2 delta AY.1 variant at an accommodation facility and the subsequent attempts to isolate individuals who tested positive.

Methods

The background that facilitated this cluster was investigated, and the conditions in which infection was established, the infection route, and the effectiveness of routine measures were evaluated. Ninety-nine staff members had been working at the accommodation facility at the time of infection, and it was estimated that 10 members were infected with the delta AY.1 variant.

Results

Our results suggest that infection of staff from a patient staying overnight should be excluded. The factors contributing to the cluster infection involved short-distance conversations with individuals wearing non-woven three-layer masks moved out of position (non-woven) and gathering together with individuals wearing non-woven masks in hypoventilated conditions. Our findings also indicate that this variant is possibly airborne and can infect individuals in enclosed spaces with poor ventilation, even when either infected or exposed individuals wear non-woven masks.

Conclusions

The routine maintenance of systems established for the detection of infections and prompt and appropriate preventive measures following the identification of positive individuals will help prevent further cluster infections.

Background

Since the confirmation of the novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in Wuhan in 2019 [1], concerning mutations have successively appeared [2] and have become a worldwide threat. In Japan, in late April 2021, the proportion of individuals infected with the SARS-CoV-2 B.1.1.7 alpha variant (alpha) strain increased, and this strain has nearly replaced the conventional 20B strain [3]. Moreover, the delta variant (delta) of the B.1.617.2 strain has been sporadically detected since May, and an increasing trend has been reported [4].

The delta variant is associated with a higher rate of secondary infections than the alpha variant, with increased susceptibility in individuals who have received only a single vaccine dose [5]. Consequently, reduced vaccine efficacy against the coronavirus disease 2019 (COVID-19) and increased risks of hospitalization and reinfection have been reported [6]. Australia has been successful in containing the spread of SARS-CoV-2; however, the virus has spread across the country due to the emergence of the delta variant [7]. In the United Kingdom, as of June 2020, the delta variant is the predominant SARS-CoV-2 strain [8]. Although delta variants with L452R and E484Q mutations have been reportedly identified [9], the AY.1 strain with a K417N mutation, which is significantly more infectious, has been reported in India, and it is referred to as delta plus by the Indian Ministry of Health [10]. In Japan, delta AY.1 was first detected in late May; however, as of July 2021, it has yet to become the mainstream novel coronavirus strain [11].

In Japan, individuals who test positive for SARS-CoV-2 can either stay at home or at an accommodation facility, such as a hotel, while undergoing treatment. In Kanagawa Prefecture, seven hotels have been serving as accommodation facilities for patients with COVID-19 (as of July 2021). In May 2021, a cluster infection with the delta AY.1 variant (in Japan, a cluster is defined as having five or more individuals infected) occurred among the staff in one of these facilities. In this study, the background conditions that led to the cluster infection were evaluated, including the situation that established the infection, the route of infection, and the effectiveness of routine preventive measures.

Methods

This study was based on a cluster of staff and patients with delta AY.1 that occurred at an accommodation facility for patients with COVID-19 operated by Kanagawa Prefecture. The duration of the investigation was based on the day of the first onset of COVID-19 in a staff member (Day 0), with Day -14 as the starting period and Day 24 as the ending period (duration of 39 days). Day 24 was defined as 2 weeks after the last day on which the last staff member experienced COVID-19, in accordance with the incubation period of the virus. Because the study targeted SARS-CoV-2 test-positive individuals, this was considered a case-series study.

Working status of the staff and zoning at the facility

Regarding the working status of the staff, written work records were assessed. Additionally, a field survey on the zoning system developed at the accommodation facility to prevent patients and staff from coming into contact with each other was conducted.

Status of mutant virus detection in patients who remained at the facility

The number of patients who entered and left the facility and the status of detection of delta AY.1 during the study period were investigated based on the individual who was in charge of the facility.

Ventilation status

The ventilation status of each area of the facility was investigated. The location and performance of the air supply/exhaust system and the air conditioning were confirmed from design drawings, and verification of the actual ventilation status was conducted using a carbon dioxide (CO₂) concentration meter (CO₂ Manager, Toa Industry Co., Ltd.). Japanese law requires that the indoor concentration of CO₂ be maintained within $\leq 1,000$ ppm, and this value was used as an indicator of the ventilation status. Eleven CO₂ concentration meters were installed at a height of 70 cm from the floor in each area (Figure 1), and after measuring the CO₂ concentrations (baseline), the areas were filled with CO₂ to approximately 2,000 ppm using a CO₂ gas cylinder. After the CO₂ concentration of each meter reached its maximum value, the CO₂ concentration was measured every 2 minutes until it decreased to a level similar to the baseline concentration.

The CO₂ concentrations were analyzed using one-way analysis of variance while considering the time course in each area. Statistical analyses were performed using the free statistical software EZR version 1.50 (Jichi Medical University, Japan) [12].

Testing and diagnosis

During the investigation period, any staff suspected of having COVID-19, such as individuals with symptoms of fever or cold, were asked to visit a medical institution and undergo polymerase chain reaction (PCR) testing for SARS-CoV-2. If positive, individuals were comprehensively diagnosed with COVID-19 by a physician. For staff without any symptoms suggestive of COVID-19, two PCR tests were performed during this period. PCR testing was performed in accordance with the method published by the National Institute of Infectious Diseases [13].

Identification of mutant viruses was performed by the National Institute of Infectious Diseases or the Regional Institutes of Public Health only when the Ct value from the PCR testing was ≤ 30 [14]. The remaining PCR samples were used for Sanger sequencing using an Applied Biosystems 3500 Genetic Analyzer (Thermo Fisher Scientific K.K., Japan), and whole-genome sequencing was performed using an iSeq 100 (Illumina Inc., CA, USA) for samples with a higher viral load.

Staff interview

A public health nurse based in the Kanagawa Prefecture retrospectively interviewed the facility staff via telephone or through face-to-face interviews regarding their contacts with PCR-positive individuals. The initial interview occurred within 1 week of testing positive for SARS-CoV-2-positive individuals and within 1 week of the PCR test for individuals who tested negative. The information collected included the work style, working days, presence or absence of symptoms for all staff members, additional time and place in the same space during the period when infection was possible, use of personal protective equipment (PPE) at the accommodation facility, hand hygiene status, type of PPE worn, having conversations with the mask off, contact with SARS-CoV-2-infected individuals in the community, date of onset, symptoms at onset, and presence or absence of vaccination for SARS-CoV-2-positive individuals.

Ethical considerations

The research protocol for this study was approved as control number 2021 by the institutional review board of the Saiseikai Yokohamashi Tobu Hospital. This research 1) was observational, using only existing materials not applicable to specific clinical research; 2) used existing information; 3) was a multicenter collaboration; 4) had no interventions; 5) did not use human specimens; 6) anonymized all individuals' information; 7) did not use personal information requiring specific handling such as medical history; 8) used information provided by outside facilities; 9) was of immense social significance; 10) involved simplified explanation and consent; and 11) was funded by Health, Labour and Welfare Science Research Grants.

Results

Working status of the staff and zoning at the accommodation facility

The lodging facility was a 234-room business hotel. The staff who operate the accommodation facilities are divided into four groups of prefectural staff, nurses, housekeepers, and security guards. Prefectural staff cooperate with public health centers to coordinate the admission of COVID-19 positive individuals and to manage the respective facilities. Nurses are responsible for managing the daily physical conditions of hospitalized patients. Housekeepers are in charge of patient food distribution, garbage pick-up, and cleaning, while guards are in charge of managing the movement of patients within the restricted areas. The average number of staff (range) members for day and night shifts were six (3–7) and one (1) for prefectural staff members, four (4) and two (2) for nurses, 10 (9–14) and two (2–3) for housekeepers, and three (3) and two (2) for security guards, respectively. The total number of staff members working throughout the cluster period was 99.

Each of the four occupations was based in a different area (the security guards were mainly outside), whereas individuals had to occasionally move across areas for the purposes of meetings or administrative tasks. The accommodation facility was zoned into two major areas: an area where patients temporarily stayed (area D) and “no patient access” areas (Figure 1). Furthermore, there was a barrier or wall at the boundary of the two areas, but the upper part of the barrier did not reach the ceiling, thereby making it possible for air to pass through.

Status of mutant virus detection in patients staying at the facility

The number of patients staying during the investigation period is shown in Table 1. The total number of patients was 1,419, and the mean number of patients per day was 51. Although not all patients could be tested for confirmation of delta AY.1, there were no reports regarding of delta AY.1 or delta detection from these patients or from infected individuals by these patients.

[Insert Tale 1 here]

Ventilation status

The layout and ventilation status of the ventilation systems in the area where each staff member was present, including area D, are shown in Figure 2. The areas for prefectural staff (area A), nurses (area B), and housekeepers (area C) were connected through corridors. Each ceiling fan (exhaust port) was designed to have a different air volume displacement; however, one ceiling fan in Area A was out of order. The number of individuals who could stay in each area consisted of 13 in area A, 24 in area B, and 14 in area C based on the required displacement (30 m³/h per person) in accordance with the Japanese law.

CO₂ concentrations were measured in each area. The temperature and humidity at the time of measurement were 22.9°C and 61.1%, respectively. The performance of CO₂ concentration meters could not be calibrated. The outdoor CO₂ concentration was approximately 430 ppm, and the error range of each measuring instrument was 0–50 ppm. At the time of cluster occurrence, air conditioners in area A were not being operated, as opposed to those in areas B, C, and D, which were in operation. Therefore, conditions were similar to the conditions at the time of the occurrence for CO₂ concentration measurement.

Changes in CO₂ concentration at each measurement point are shown in Figure 3. Unlike in areas A and B, CO₂ decreased to the baseline within approximately 30 minutes in areas C and D. Moreover, the decrease in CO₂ concentration immediately after the beginning of measurement was rapid in area B, but showed a gradual and decreasing trend (Air convection due to the air conditioner was a highly likely cause, which may have exceeded the suction force at the exhaust port). In addition, differences in CO₂ concentrations between the areas were not statistically significant. However, although ventilation range in area A was within legal requirements, ventilation was slightly poor compared to other areas because the exhaust port fan was broken.

Testing and diagnosis

Staff who did not exhibit symptoms suggestive of COVID-19 underwent PCR testing twice during the cluster period, and individuals who tested negative were defined as infection-free. Thirteen staff members were identified with symptoms suggestive of COVID-19. Of the 13 members, nine were required to visit a medical institution and underwent PCR testing, where they tested positive, and they were thus diagnosed with COVID-19 by the lead physician. The remaining four staff members did not visit a medical institution, since onset was on the day of the group testing. Instead, these individuals underwent PCR testing during group testing (Figure 4a). Of these four members, three tested negative and one was found to be SARS-CoV-2 positive (and was later diagnosed with COVID-19 by a physician). Since these three members also tested negative in a separate testing session that was performed two days after the initial tests, infection with SARS-CoV-2 was ruled out.

In the 10 PCR-positive staff members, except for one member with low viral load in the sample (received one vaccination dose), a genomic analysis was performed. Sanger sequencing analysis confirmed that the virus detected in the remaining nine members had K417N, L452R mutations that were characteristic of delta AY.1. In addition, whole-genome sequence analysis revealed that samples from five members with sufficient viral loads included viruses with genomes that were molecularly homologous, did not show single nucleotide polymorphisms, and thus had completely identical molecular structures. The glycosylation mutation information for SARS-CoV-2 spike proteins in these five samples and the accession IDs registered into the Global Initiative on Sharing Avian Influenza Data [GISAID] (<https://www.gisaid.org/>) are shown in Table 2.

[Insert Tale 2 here]

Staff interview

The health of the accommodation facility staff was routinely observed, and physical deconditioning was not observed in any of the staff members immediately prior to cluster infection. A line listing of facility staff who were SARS-CoV-2 PCR-positive is provided in Table 3 and the related epidemiological curves are provided in Figure 4b. The first episode occurred in a nurse (Case 1). There was no infection registered in nurses working together with Case 1 on night shift. The only contact between Case 1 and prefectural staff (Case 2 or Case 3) was for an approximately 5-min conversation regarding work-related tasks in Area B, during which everybody wore non-woven masks, and for approximately 5 min/meeting during staff meetings (up to 26 individuals) twice daily in Area A (where also all staff wore non-woven masks).

[Insert Tale 3 here]

Contact between Case 1 and housekeepers (Cases 4 and 6) lasted for approximately 10 min while putting on and removing PPE, and for approximately 5 min during the aforementioned general meeting and during daily communications regarding work-related tasks.

Other possible infection risks included telephone calls for approximately 30 min per day by prefectural staff in Area C where the housekeepers stayed (there was a witness stating that non-woven masks were occasionally worn incorrectly), masks being moved out of position, and conversations during light meals with individuals in the same occupation (up to six prefectural staff work in Area A and up to 10 housekeepers work in Area C), conversations during daily work while wearing non-woven masks, and smoking together in groups of 4–5 housekeepers. Hand hygiene was performed before and after putting on and removing PPE, when entering each staff area, and just before eating and drinking.

Vaccination status, symptoms at onset and oxygen saturation on admission, and prognosis of PCR-positive staff are shown in Table 4. Approximately 3 weeks before the onset of Case 4, the individual received one dose of the BNT162b2 (Pfizer-BioNTech) vaccine against COVID-19. The remaining positive

individuals were not vaccinated. Of the 10 PCR individuals who tested positive, nine developed the disease (one patient was asymptomatic), and four (two males and two females) were hospitalized, but their conditions improved, and they were thus discharged from the hospital.

[Insert Tale 4 here]

Measures taken after the identification of positive individuals

Measures to prevent the spread of cluster infection included the following mandatory measures: cleaning of exhaust and air vent filters, enhancing ventilation (opening windows) from Day 7, prohibiting of having masks off or out of position during breaks, etc., and thorough hand hygiene. On Day 8, the infection countermeasure team from the Kanagawa Prefecture visited the facility to confirm the situation and to instruct all staff members to wear N95 respirators at all times. N95 respirators are respiratory protective equipment originally used to prevent infection to wearers [15]. However, since N95 respirators have a higher filtration ability and fit compared to non-woven masks and they have been suggested to be effective in preventing infection to others [16], a mandate was given to wear them.

Discussion

This example situation underlines that conversations at short distances with non-woven masks either off or out of position or crowding in a hypoventilated state may be significant risks for infection with SARS-CoV-2. In addition, depending on the ventilation status, there was a possibility of infection during short-term (approximately five minutes contact) even within the ventilation standards specified by Japanese law. Although it cannot be concluded that conversations with non-woven masks, even when worn appropriately, is a high risk of infection, this should not be excluded.

SARS-CoV-2 infection may be passed on through aerosols [17–19]. The risk increases even further if the distance is short [20]. Consequently, in the present example, infection with SARS-CoV-2 was likely to have spread mainly by aerosol. In all cases, it is inferred that the cause of the cluster infection was the environment wherein there was exposure to aerosols at short distances, although the time of exposure varied. In addition, there were cases where SARS-CoV-2 infection was suggested despite wearing non-woven masks and eye protection on a daily basis [21]. This is because a recent experiment showed that non-woven masks only filtered 38.5% of aerosols when worn normally [22], and there was a possibility that the aerosol entered through the gaps in the nose and cheeks, thus causing SARS-CoV-2 infection. From this example, limited protection against SARS-CoV-2 infection offered by non-woven masks was inferred.

There is a concern that infection may occur due to aerosols under poor ventilation even when a non-woven mask is worn. Wearing a mask can effectively protect individuals against SARS-CoV-2 infection; however, complete prevention is difficult [23]. In this example, a maximum of 26 individuals had to coexist in the same area with each other for 5 min—each in the morning and evening—in a space 15.8 $([300 + 110]/26)$ m³/h (area A), where only 13 individuals were allowed by Japanese law. Despite the short time of these meetings, this increased the risk of infection even though all staff members wore non-woven masks. While a case of infection with conventional SARS-CoV-2 has been reported at a ventilation rate of approximately 0.9 L/s (0.324 m³/h) without wearing a mask [24], infection in this example managed to spread despite the fact that this establishment had a 50-fold increased ventilation rate. Therefore, this spread can be justified by the higher infectious nature of the delta AY.1 variant, which contains an additional K417N mutation. Moreover, area A was also found to have particularly poor ventilation conditions when tested with CO₂, which is a likely risk factor for cluster infection.

This example was a cluster infection with delta AY.1. The delta variant is associated with a higher rate of secondary infection compared to the alpha variant [25], suggesting that infection may have spread due to the higher infectious nature of delta AY.1. In actuality, all four cases were in contact with one other for a very short period of time while wearing non-woven masks appropriately, thus suggesting the effect of delta AY.1. However, other infection pathways could also be adequately explained with other conventional viruses; thus, routine implementation of conventional measures was likely to contribute to the prevention of large-scale cluster infections.

The index case in this example could not be confirmed. Case 1 also worked at a lodging care facility in another prefecture. However, the lodging care facility did not report any events suggestive of infection, and the individual rarely ate or went outside except for work. Although the possibility of Case 2 being the index case could not be excluded, there was no behavior that was a risk for infection before the onset. In both Cases 1 and 2, delta AY.1 was not detected in individuals living in the same household and, subsequently, these cases could not be determined to be index cases.

Additionally, SARS-CoV-2 may have been spread in this facility by a staff member who did not exhibit related disease symptoms. However, since none of the staff members who were confirmed to be PCR-positive during group testing performed since Day 6 was asymptomatic during that period, and physical deconditioning was not reported in any of the staff members prior to the cluster infection, the possibility that SARS-CoV-2 was brought in by asymptomatic pathogen carriers was ruled out.

Furthermore, although we could not exclude the possibility of infection from patients who stayed overnight, the risk of infection was estimated to be low. The reasons were that there had been no cases of delta AY.1 infection reported in the Kanagawa Prefecture at the time this cluster infection occurred, and because it was unlikely that patients admitted at the time had delta AY.1. In addition, ventilation, and the development of a zoning system for patients and staff were thoroughly implemented, and patients were always wearing masks and only resided on the first floor for a brief period. Furthermore, when staff members were in contact with patients, they were obliged to wear N95 respirators, face shields, gowns, and gloves, and hand hygiene was performed without any issues under certain training, indicating that the risk of infection was extremely low. Regarding the passage of air observed near the ceiling of area C and D, the possibility that the event originated from a housekeeper staying in area C was unlikely, and it is difficult to consider transmission of the infection from patients to the housekeepers.

SARS-CoV-2 is highly infectious on the day of onset and for approximately one or two before or after the day of onset [26]. Thus, Case 9 working on the day of onset and Case 10 working on the day before onset may have caused infection to individuals around them; however, no secondary infection from Cases 9 and 10 was verified. The most significant factor considered to have contributed to the absence of infection was that Cases 9 and 10 were working while wearing N95 respirators, which probably prevented the spread of infection. However, due to the limitations related with our findings and due to the limited sample size, further validation is required to confirm the ability of N95 respirators to prevent the spread of infection.

In Japan, individuals who have been in contact with infected individuals and who are considered by public health centers to be at high risk of infection (i.e., individuals who share space with people who have tested positive within the infection window) are basically required to be quarantined at home [27]. However, in this example, if all individuals who came into contact with those infected were to be quarantined, the operation of accommodation facilities would be unrealistic. This example suggests that, in such instances, the risk of infection could be reduced when individuals who come into contact with infected patients, and who are at risk of infection, wore N95 respirators. Of course, the risk is higher in symptomatic individuals or in those who are asymptomatic but PCR-positive. Consequently, individuals that should be included are those who come into contact with infected people and who are asymptomatic PCR-negative.

This study had three limitations. First, molecular analyses of the SARS-CoV-2 detected in all patients before and after the onset of the cluster infection was not performed, and the relationship between this example and the infection transmission route in patients was unknown. Second, the reliability of the time of contact and detailed contact status (such as the situation where non-woven masks were supposedly moved out of position) of staff members working during the cluster infection could not be guaranteed. The status of occurrence of the cluster infection may have been underestimated or overestimated since all assessments relied on reports from positive individuals. Thus, this cluster is specific to this example, and there are limitations toward generalizing the situation. Finally, establishing Case 4 as being infected with delta AY.1 and establishing whether some cases had the same molecular homology could not be achieved. However, considering the status of infection and the history of contacts with individuals who tested positive, it is highly likely that all cases were infected with the same virus, and, given the infection status and since there were no other risks of infection, the cases were assessed as delta AY.1.

Conclusions

SARS-CoV-2 has been suggested as an airborne infection that may be transmitted through the release of aerosols from individuals who have tested positive. The delta AY.1 variant has been suggested to be infectious in enclosed spaces with poor ventilation, even if both infected and exposed individuals wear non-woven masks. In addition, the use of N95 respirators has been suggested as an effective counter-measuring option to prevent infection. However, for this to be guaranteed, the status of infection should be understood based on rapid and extensive group testing at the time of cluster infection, provided that the purpose is not to infect the other party or prevent further infections when there is a shortage of human resources.

Abbreviations

SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; COVID-19, coronavirus disease 2019; PCR, polymerase chain reaction; PPE, personal protective equipment

Declarations

Ethics approval and consent to participate

The research protocol for this study was approved as control number 2021 by the institutional review board of the Saiseikai Yokohamashi Tobu Hospital. This research 1) was observational, using only existing materials not applicable to specific clinical research; 2) used existing information; 3) was a multicenter collaboration; 4) had no interventions; 5) did not use human specimens; 6) anonymized all individuals' information; 7) did not use personal information requiring specific handling such as medical history; 8) used information provided by outside facilities; 9) was of immense social significance; 10) involved simplified explanation and consent; and 11) was funded by Health, Labour and Welfare Science Research Grants.

Consent for publication

We consent to be published in BMC Public Health. We have received consent from all participants of the study.

Availability of data and materials

The data used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

All authors declare that they have no competing interest.

Funding

This study was supported by a grant from the Health and Labour Sciences Research Project (Research for establishing in-hospital and in-facility infection control measures against new coronavirus infections), which was aimed at establishing nosocomial and institutional control measures against novel coronavirus infections (grant number 20CA2022).

Authors' contributions

Takayuki Ohishi was the chief investigator and responsible for the data analysis and organization. Hiroyuki Kunishima and Takuya Yamagishi confirmed the authenticity of all the raw data. All authors contributed to the writing of the final manuscript. All authors have read and approved the final manuscript.

Acknowledgements

Not applicable

References

1. Zhu N, Zhang D, Wang W, Li X, Yang B, Song J, et al. A novel coronavirus from patients with pneumonia in China, 2019. *N Engl J Med*. 2020;382:727–33. doi:10.1056/NEJMoa2001017.
2. Lazarevic I, Pravica V, Miljanovic D, Cupic M. Immune evasion of SARS-CoV-2 emerging variants: What have we learnt so far? *Viruses*. 2021;13:1192. doi:10.3390/v13071192
3. National Institute of Infectious Diseases. Current Situation of Infection, May 12, 2021. <https://www.niid.go.jp/niid/en/2019-ncov-e/10381-covid19-ab34th-en.html> Accessed 23 Oct 2021.
4. National Institute of Infectious Diseases. Current Situation of Infection, June 6, 2021. <https://www.niid.go.jp/niid/en/2019-ncov-e/10429-covid19-ab37th-en.html> (2021) Accessed 23 Oct 2021.
5. Kupferschmidt K, Wadman M. Delta variant triggers new phase in the pandemic. *Science*. 2021;372:1375–6.
6. Khan A, Khan T, Ali S, Aftab S, Wang Y, Qiankun W, et al. SARS-CoV-2 new variants: Characteristic features and impact on the efficacy of different vaccines. *Biomed Pharmacother*. 2021;143:112176. doi:10.1016/j.biopha.2021.112176.
7. Nunes-Vaz R, Macintyre CR. Observations on the current outbreak of the SARS-CoV-2 Delta Variant in Sydney. 2021;3. doi:http://doi.org/10.31646/gbio.121.
8. Public Health England. SARS-CoV-2 variants of concern and variants under investigation in England: Technical briefing 17. 25 June 2021. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/996740/Variants_of_Concern_VOC_Technical_Briefing_17.pdf Accessed 23 Oct 2021.
9. Singh J, Rahman SA, Ehtesham NZ, Hira S, Hasnain SE. SARS-CoV-2 variants of concern are emerging in India. *Nat Med*. 2021;27:1131–3. doi:10.1038/s41591-021-01397-4.
10. India's Ministry of Health. Union Health Ministry advises Maharashtra, Kerala and Madhya Pradesh on Delta AY.1 Variant, currently a Variant of Concern. <https://content.pib.iostechtools.com/1729467/web.html>. Accessed 23 Oct 2021.
11. National Institute of Infectious Diseases. Current situation of infection, June 16, 2021. <https://www.niid.go.jp/niid/en/2019-ncov-e/10450-covid19-ab39th-en.html> Accessed 23 Oct 2021.
12. Kanda Y. Investigation of the freely available easy-to-use software 'EZ' for medical statistics. *Bone Marrow Transplant*. 2013;48:452–8. doi:10.1038/bmt.2012.244.
13. Hirotsu Y, Mochizuki H, Omata M. Double-quencher probes improve detection sensitivity toward severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in a reverse-transcription polymerase chain reaction (RT-PCR) assay. *J Virol Methods*. 2020;284:113926. doi:10.1016/j.jviromet.2020.113926.
14. Mishra S, Mindermann S, Sharma M, Whittaker C, Mellan TA, Wilton T, et al. Changing composition of SARS-CoV-2 lineages and rise of Delta variant in England. *EClin Med*. 2021;39:101064. doi:10.1016/j.eclinm.2021.101064.
15. Azap A, Erdinç FS. Medical mask or N95 respirator: When and how to use? *Turk J Med Sci*. 2020;50:633–7. doi:10.3906/sag-2004-199.
16. Ueki H, Furusawa Y, Iwatsuki-Horimoto K, Imai M, Kabata H, Nishimura H, et al. Effectiveness of face masks in preventing airborne transmission of SARS-CoV-2. *mSphere*. 2020;5:e00637. doi:10.1128/mSphere.00637-20.
17. Stadnytskyi V, Bax CE, Bax A, Anfinrud P. The airborne lifetime of small speech droplets and their potential importance in SARS-CoV-2 transmission. *Proc Natl Acad Sci USA*. 2020;117:11875–7. doi:10.1073/pnas.2006874117.
18. Ma J, Qi X, Chen H, Li X, Zhang Z, Wang H, et al. Coronavirus disease 2019 patients in earlier stages exhaled millions of severe acute respiratory syndrome coronavirus 2 per hour. *Clin Infect Dis*. 2021;72:e652–e4. doi:10.1093/cid/ciaa1283.
19. Buonanno G, Stabile L, Morawska L. Estimation of airborne viral emission: Quanta emission rate of SARS-CoV-2 for infection risk assessment. *Environ Int*. 2020;141:105794. doi:10.1016/j.envint.2020.105794.
20. Chu DK, Akl EA, Duda S, Solo K, Yaacoub S, Schünemann HJ, et al. 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;395:1973–87. doi:10.1016/S0140-6736(20)31142-9.
21. Klompas M, Baker MA, Rhee C, Tucker R, Fiumara K, Griesbach D, et al. A SARS-CoV-2 cluster in an acute care hospital. *Ann Intern Med*. 2021;174:794–802. doi:10.7326/M20-7567.
22. Clapp PW, Sickbert-Bennett EE, Samet JM, Berntsen J, Zeman KL, Anderson DJ, et al. Evaluation of cloth masks and modified procedure masks as personal protective equipment for the public during the COVID-19 pandemic. *JAMA Intern Med*. 2021;181:463–9. doi:10.1001/jamainternmed.2020.8168.
23. McPeck R, Magori P. Masking significantly reduces, but does not eliminate COVID-19 infection in a spatial agent-based simulation of a University dormitory floor. *medRxiv*. 2021. doi:10.1101/2021.09.13.21263458.
24. Li Y, Qian H, Hang J, Chen X, Cheng P, Ling H, et al. Probable airborne transmission of SARS-CoV-2 in a poorly ventilated restaurant. *Build Environ*. 2021;196:107788. doi:10.1016/j.buildenv.2021.107788.

25. Allen H, Vusirikala A, Flannagan J, Twohig KA, Zaidi A, COG-UK Consortium, et al. Increased household transmission of COVID-19 cases associated with SARS-CoV-2 Variant of Concern B.1.617.2: a national case-control study. <https://khub.net/documents/135939561/405676950/Increased+Household+Transmission+of+COVID-19+Cases+-+national+case+study.pdf/7f7764fb-ecb0-da31-77b3-b1a8ef7be9aa>. Accessed 23 Oct 2021.
26. He X, Lau EHY, Wu P, Deng X, Wang J, Hao X, et al. Temporal dynamics in viral shedding and transmissibility of COVID-19. *Nat Med.* 2020;26:672–5. doi:10.1038/s41591-020-0869-5.
27. Seto J, Aoki Y, Komabayashi K, Ikeda Y, Sampei M, Ogawa N, et al. Epidemiology of coronavirus disease 2019 in Yamagata Prefecture, Japan, January–May 2020: The importance of retrospective contact tracing. *Jpn J Infect Dis.* 2021;74:522–9. doi:10.7883/yoken.JJID.2020.1073.

Tables

Table 1. Transition of the number of patients accepted at the accommodation facility during the cluster period.

Case No.	Day-14	Day-13	Day-12	Day-11	Day-10	Day-9	Day-8	Day-7	Day-6	Day-5	Day-4	Day-3	Day-2	Day-1	Day0	Day1	Day2	Day3
Number of newly accepted patients	1	7	1	1	0	8	10	10	6	5	8	14	15	10	10	7	3	19
Number of discharged patients	12	6	6	5	9	7	7	4	5	5	2	1	3	6	13	9	5	6
Total number of patients accepted	46	47	42	38	29	30	33	39	40	40	46	59	71	75	72	70	68	81
Day 0 was the day of the onset of the disease. The accommodation facility was temporarily closed on Day 12.																		

Table 2. GISAID accession ID and amino acid mutations in the spike glycoprotein.

Case No.	Accession ID	Spike glycoprotein												
		19	95	142	156	157	158	258	417	452	478	614	681	950
1	EPI_ISL_3191707	R	I	D	G	del	del	L	N	R	K	G	R	N
2	EPI_ISL_3191716	R	I	D	G	del	del	L	N	R	K	G	R	N
5	EPI_ISL_3191717	R	I	D	G	del	del	L	N	R	K	G	R	N
9	EPI_ISL_3191718	R	I	D	G	del	del	L	N	R	K	G	R	N
10	EPI_ISL_3191719	R	I	D	G	del	del	L	N	R	K	G	R	N
del: deletion														

Table 3. Line list of SARS-CoV-2-positive individuals among the staff of the accommodation facility.

1	N	NS	NS*	O	SC	P														
2	P	NS			DS	O		SC	P											
3	P	DS	DS	DS				O	SC	P										
4	H	DS			DS			O		SC		P								
5	P		DS		NS			DS	O	SC	P									
6	H	DS	DS	DS	DS	DS	DS	DS	O	SC	P									
7	H			DS		DS	DS	DS	DS	O	SC		P							
8	H			DS	DS		DS			O	SC	P								
9	P			DS	DS	DS	DS	DS	NS		DS	DS		O	SC		P			
10	H	DS	DS	DS	DS	DS		DS	DS	DS	DS	DS	DS	DS	O		SC			P

N: Nurses, PS: Prefectural office staff, H: Housekeeper, DS: Day shift, NS: Night shift, O: Onset (fever, sore throat, etc.), P: PCR-positive, SC: Sample collection for PCR test, Gray: Infectious period considering the incubation period

* Night shift at another accommodation facility

Table 4. Vaccination status, symptoms at onset and oxygen saturation on admission, and prognosis of PCR-positive staff.

Case No.	Ager	Gender	Vaccination status	Symptoms at onset	Oxygen saturation on admission	Prognosis
1	43	Female	None	Fever	91%	Good
2	62	Male	None	Sore throat	92%	Good
3	63	Male	None	Fever Cough Headache	Not hospitalized	Good
4	51	Female	Received one dose	Cough	Not hospitalized	Good
5	52	Male	None	Fever	93%	Good
6	43	Male	None	Fever Malaise	Not hospitalized	Good
7	21	Male	None	Sore throat	Not hospitalized	Good
8	20	Male	None	Sore throat	Not hospitalized	Good
9	22	Male	None	Asymptomatic	Not hospitalized	Good
10	36	Female	None	Fever	91%	Good

Figures

Figure 1

Floor plan and ventilation at the accommodation facility (1st floor).

Figure 2

Installation position of the carbon dioxide measuring points.

Figure 3

Changes in carbon dioxide concentrations at each measurement point over time. A area: Prefectural office staff area, B area: Nurses' area, C area: Housekeepers' area, D area: Patients' area. $P = 0.354$ for changes over time in each area (one-way analysis of variance).

Figure 4

Test timings and onset of disease in PCR-positive people. **(a)** COVID-19 epicurve at the accommodation facility. All staff wore N95 respirators from day 8. **(b)** Polymerase chain reaction mass screening test for the accommodation staff. Only one person was positive on the screen test. Nine people were found to be positive outside the screen test.