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Original Article

Control of an outbreak of COVID-19 at a tertiary hospital in Taiwan

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Abstract *Background:* Coronavirus disease 2019 (COVID-19) has circulated in Taiwan since late 2019. Healthcare facilities are vulnerable to COVID-19 outbreaks due to clusters of symptomatic patients and susceptible hosts. Prompt control of outbreaks is crucial. In May 2021, an index case of COVID-19 was detected at Far Eastern Memorial Hospital (FEMH) in New Taipei City, Taiwan, 3 days after hospital admission, spreading to 26 patients and staff. Herein we evaluate control of this COVID-19 outbreak.

Methods: To control the outbreak, the index case ward was closed, and large-scale COVID-19 testing (RT PCR) was performed for all inpatients, caregivers and healthcare workers (HCWs). All exposed persons were quarantined. Thorough investigation was conducted to analyze the transmission route.

Results: The outbreak comprised 12 patients, 12 caregivers, and 3 HCWs. Seven patients expired and the remaining cases recovered. Overall, 456 patients/caregivers and 169 HCWs were quarantined. Analysis showed that longer exposure time was the main cause of HCW infection; all three infected HCWs were primary-care nurses related to the index case. To diminish hidden cases, all hospitalized patients/caregivers received PCR examinations and all results were negative. Thereafter, all patients/caregivers routinely received PCR examination on admission. Hospital-wide PCR screening for HCW detected 4 positive HCWs unrelated to this outbreak, and a second-round of screening detected 2 more cases, with no additional cases during the following 6 months.

Conclusion: Prompt infection control measures and large-scale PCR screening can control a COVID-19 outbreak within 2 weeks. Exposure time is the major risk factor for HCW infection. Copyright © 2022, Taiwan Society of Microbiology. Published by Elsevier Taiwan LLC. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

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Introduction

Coronavirus disease 2019 (COVID-19), which is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), started in Wuhan, China, in December 2019 and was declared a Public Health Emergency of International Concern by the World Health Organization (WHO) on January 30, 2020.¹ Taiwan was not seriously affected until COVID-19 cases emerged rapidly in northern Taiwan, mainly linked to exposure in the Wan-Hua District, Taipei, in early May 2021. Clusters of community-hospital transmissions with subsequent nosocomial outbreaks were noticed thereafter.²

Far Eastern Memorial Hospital (FEMH) is a medical center located in Ban-Chiao District, New Taipei City, Taiwan. The hospital has 1415 beds with a daily average of 1000 hospitalized cases, 6500 outpatient visits, and 300 emergency department (ED) visits. At that time, the hospital staff comprised 3547 fulltime healthcare workers, 769 outsourced workers, and 770 volunteers. Many patients also had caregivers who accompanied them to the hospital. An outbreak due to COVID-19 was detected in May 2021. The index case, who had a history of coronary artery disease, chronic obstructive pulmonary disease, and hypertension, visited the ED on May 9, 2021, complaining of severe cough and shortness of breath for the past three days. Nasal cannula oxygen, inhaled bronchodilator, intravenous steroid and empirical antibiotic were administered. A chest x-ray (CXR) showed bilateral mild infiltrates. Under impression of community-acquired pneumonia, he was admitted to a pulmonary ward on May 10. After admission, empirical antibiotics and inhaled bronchodilators were continued, but the steroid was discontinued. Fever flared up again on May 12. His daughter then informed the medical team that the patient had made frequent visits to tea shops in the Wan-Hua District. PCR test for COVID was performed on 5/13 and was positive that night (E-Ct: 19.44, RdRp-Ct: 22.47). His condition deteriorated on the next day and he was intubated and transferred to a negative pressure intensive care unit.

Coronavirus is well-known for causing nosocomial outbreaks as reported in previous studies, including SARS, MERS, and COVID-19 infections.³ The Taiwan CDC had issued a protocol for management of COVID cases detected incidentally in the hospital. For a single case without local transmission, quarantine of the index case and main care team was sufficient. On the contrary, for multiple cases detected in the same ward, ward closure and comprehensive quarantine procedures were enforced. On 5/14, we performed the first round of PCR to trace close contacts with the index case, and detected two more cases. Emergent containment protocol was initiated immediately.

Methods

Outbreak investigation and contact tracing

Contact tracing involved all persons in the pulmonary ward, including HCWs, patients, caregivers, visitors, and patients/HCWs in the ED who had prolonged exposure time to the index case. According to the guidelines of Taiwan CDC, there are two levels of exposure risk (contact with the

index case within 3 days): (1) Directly exposed persons are those who were within two meters of a symptomatic patient without the use of N95 respirator mask and droplet/contact precautions for more than 15 min (high-risk exposure). (2) Indirectly exposed persons are those who were present in the same unit but the exposure time was short or not in the same room (low-risk exposure).^{4,5} All contacts with confirmed COVID-positive patients within 3 days who met the criteria were traced, including: (1) Within 2 m of a confirmed case within 24 h without proper protection who were in close contact for more than 15 min; (2) Exposure to droplet particles and medical treatment (aerosol generating procedures, AGP) of a confirmed case without proper protection; (3) People in the same room as the confirmed case and caregivers or visitors.⁶

After documented local transmission, the ward was closed on May 15. We followed Taiwan CDC's policy to quarantine all patients/caregivers/staffs related to this ward and had a stricter screening policy for PCR screening. Universal PCR was performed for everyone in the beginning, and repeated every 2–3 days or when the quarantine case had symptoms. A final round of PCR was performed on Day 14 if the quarantine case was still hospitalized and also for quarantined healthcare workers. Current hospitalized cases were only discharged after negative PCR tests (with further quarantine in the community). Every patient, caregiver and HCW received repeated PCR tests. Since no HCWs at the index ward used N95 respirator masks at that time, all HCWs at the ward were quarantined. In contrast, all HCWs at the ED wore N95 masks during working hours and none were quarantined. All quarantined patients/caregivers received follow-up PCR tests every 2–3 days. The quarantine duration was 14 days.

PCR and rapid antigen test

The Roche 6800 analyzer (Roche, Basel, Switzerland) is used for performing regular RT PCR. The Liat PCR (Roche, Basel, Switzerland) is used for emergent conditions when rapid turnaround time is indicated. The LabTurbo platform (LabTurbo Biotech, Taipei, Taiwan) is used for pooling saliva samples of HCWs. Rapid antigen test (RAT) produced by TaiDoc Technology, New Taipei City, Taiwan, is used for rapid screening at the ED, hemodialysis center, and for outpatient procedures, etc.

Infection control policy modification after the outbreak

General infection control policy at FEMH before the 2021 surge included that everyone should wear a mask before entering the hospital; travel, occupation, contact, and cluster history (TOCC) must be provided for all admissions; patients admitted to the ED with fever and any suspicion of COVID-19 must receive PCR testing; suspicious cases must be quarantined in a single patient room within a specialized ward for this pandemic; alcohol sanitizers must be placed at all hospital entrances, elevators, and crowded areas; and HCWs should be encouraged to receive vaccinations. However, these policies were not enough to avoid the upcoming surge of COVID cases.

In order to avoid admitting COVID cases to unrestricted areas, every patient and their caregiver were tested with PCR before being admitted to the ward. Basically, the screening policy changed from targeted screening to universal screening. For hospitalized patients and their caregivers, the rapid antigen test was repeated weekly. Two rounds of hospital-wide PCR were performed for HCWs, and PCR was repeated weekly for workers in high-risk areas such as the ED and specialized wards. Rapid antigen tests were applied in the ED, OPD procedure theater, hemodialysis center, endoscopy centers, and so on. If RAT was positive, the patient was transferred to the ED directly.

To minimize a patient's stay in the ED, specialized wards/ICUs were expanded with wooden walls to create buffer zones for HCWs (capacity of negative pressure rooms was limited, only 11 rooms). Non-emergent medical services were postponed. If a case was suspected to have COVID-19 but the first PCR was negative, the patient was kept in a single room and a second PCR was performed on the third day to exclude the possibility of missing a true case. Patients and caregivers were advised to stay in their rooms wearing masks and avoid clustering at pantry rooms or rubbish rooms. Furthermore, in June 2021, the government started to divert positive cases without risk factors or warning signs to quarantine hotels. All inhalational drugs were regulated to reduce aerosol generation.

Results

On May 15, additional positive cases were detected from different rooms at the index ward. The patient in the adjacent bed of the index case during his ED stay was also COVID-19 positive but was not admitted to the index ward. Thus, a second ward was also closed in fear of spreading of the virus. Subsequently, positive cases were detected on a daily basis. Overall, the outbreak comprised 12 patients, 12 caregivers, and 3 HCWs. The epidemic curve is shown in Fig. 1. In total, 456 patients/caregivers and 169 HCWs were quarantined (Table 1). Quarantined cases are grouped into primary and secondary exposure according to risk identification of contact time/distance and protective measures. The last positive case was a nurse who had a positive result on May 30 before she returned to work. Outcomes of all cases are shown in Table 2. Mortality was 58% for patients and zero for caregivers and nurses.

We attempted to analyze the transmission route of the index case. The possible transmission route is shown in Figs. 2 and 3. The transmission that occurred at the ED was simple and only spread to the patient next to the index case and her caregiver. Other subsequent cases can be divided into 3 subgroups. Group 1 was in the same room with the index case or adjacent rooms under the care of the same day-shift nurse. Group 2 included patients in rooms not directly adjacent to the index case room, but who were cared for by another day-shift nurse. However, during the night shift, Groups 1 and 2 were cared for by the same nurse. Group 3 included sporadic patients/caregivers. The virus may have spread to Group 3 at a public area in the index ward, such as the pantry room or rubbish room. Among the 169 HCWs under investigation, only 3 nurses turned out to be infected. Total 14 doctors were quarantined due to exposure and had received PCR every 2–3 days

before they returned to work. No doctor was PCR positive during the quarantine period (Most of them had received vaccination in March/April 2021). We calculated the exposure time of all HCWs and found that the 3 nurses carried the longest exposure period. Two HCWs were day-shift nurses of the index or subsequent cases and the remaining one was the night-shift nurse caring for the same groups. Numbers of PCR testing and route of transmission was shown in a Fig. 5. The index case had regular use of inhaled bronchodilator. Moreover, most patients at this ward had received inhalation therapy or aerosol O2 mask use which may carry higher risk of virus spreading. The environmental surfaces contaminated by the virus could potentially have contributed to the outbreak.⁷ We only performed environmental screening after preliminary cleaning and more than 100 environmental samples were collected for PCR, from door handles, beds, toilet seats, electric buttons, bedside tables and chairs, etc. Positive results were only detected from the indoor handle of the index room. It is possible the virus exists at other sites but was eliminated after the cleaning, but the index room is definitely the most contaminated area.

To diminish hidden cases at the center, all hospitalized patients/caregivers received PCR examinations and all results were negative. After the outbreak, all patients/caregivers received PCR examination routinely on admission. The first round of hospital-wide PCR screening for HCW detected 4 positive HCWs (1 physician, 1 nurse, 2 physicists at the radio-oncology department) unrelated to this outbreak, and a second-round of screening one week later detected 2 more cases (1 from food service, 1 from linens service). No HCW infection was detected afterwards during the following 6 months (Fig. 4). Delivery of the first doses of vaccine at FEMH was below 30% before the outbreak, but reached 90% by May 20, shortly after identification of the index case.

During management of the outbreak, the case numbers of COVID increased rapidly in northern Taiwan. Foreseeing the medical need and handling of the outbreak, we stopped non-emergent services and started to transform regular wards/ICUs to COVID specialized wards/ICUs to ramp up medical services capacity.² At FEMH, about 60% of daily admissions were from the outpatient department (OPD) and 40% from the ED. The number of hospitalized patients decreased from over 1000 to 471 by 5/22, due to the outbreak and postponing non-emergent services. COVID cases comprised 30% of hospitalized cases at the peak of the surge in early June. New COVID cases were found in the ward and ED, but only a small outbreak involved 4 patients/caregivers and one symptomatic nurse was detected after the outbreak under the stricter infection control measures. In total, 10 HCWs at FEMH were infected with COVID in the surge of May 2021. The overall prevalence rate was about 0.2% among HCW, very close to the approximate rate of 0.3% at Ban-Chiao District, where the hospital is located, at the same time.

Discussion

Coronavirus is notorious for its ability to cause nosocomial infection. When COVID cases accumulate in the community, transmission within the hospital and its subsequent

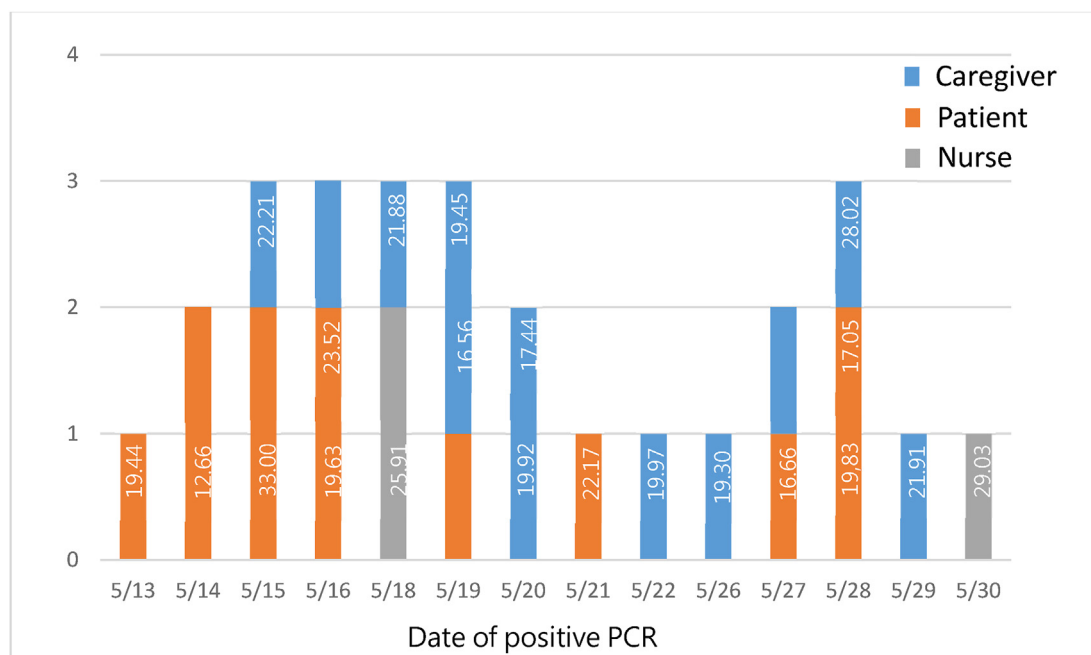


Figure 1. Epidemiology curve of PCR-confirmed cases.

Table 1 Number of quarantined cases.

	Patients, caregivers, visitors		
	High risk exposure	Low risk exposure	Total
Index ward	200	27	227
Second ward	4	225	229
	204	252	456
	Healthcare workers		
	High risk exposure	Low risk exposure	Total
Index ward	53	55	108
Second ward	3	58	61
	56	113	169

outbreak is unavoidable, as all patients, caregivers and healthcare workers live within the same community. In the present study, we have shown that a single index case spread the virus to 26 subsequent cases. We learned that applying stricter infection control measures and universal PCR/RAT screening, an outbreak of COVID-19 can be controlled within 2 weeks. Exposure time is the major risk factor for infecting HCWs.

The index case came to our ED with fever and suspected community-acquired pneumonia and was admitted under the impression of chronic bronchitis with acute exacerbation. No PCR for COVID was done at the ED or immediately after hospitalization. Although the importance of patients' TOCC history was emphasized repeatedly, in real-world practice, taking history alone was not enough to determine whether patients are at risk for COVID. Moreover, the index case did not completely or truthfully inform hospital staff about his contact history initially, and the risk factors for acquiring COVID, such as being in a special area, risky

occupation or behaviors, have changed rapidly. Relying on TOCC alone has its limitations. Earlier recognition of an index case might limit the extent of the outbreak.⁸ By performing universal PCR at admission for both patients and their caregivers, the risk of spreading the virus in the hospital can be reduced or prevented.^{9,6} However, sometimes a second PCR may be necessary for patients whose presentation is possibly a COVID-related illness such as pneumonia or persistent fever, to completely exclude the possibility of COVID.

Also, although the index case had fever and respiratory symptoms, he did not always wear a surgical mask during his stay in the ward, and he was chatting with staff and other patients frequently. He received inhalation bronchodilator therapy and oxygen therapy. In spite of universal masking being advocated in Taiwan, especially in the hospital, it is not uncommon for patients or caregivers to ignore the regulation. The spread of virus in an environment depends on the behavior of the carriers.¹⁰ Originally, a ward is designed to be open and patients/caregivers are encouraged to communicate with each other, to provide mutual support and understanding. However, when a new virus emerges and people lack immunity against the virus, talking to each other or sharing food together becomes risky behavior, which is pretty common among caregivers. We believe the behavior of our index case contributed to the spread of the virus in the ward. In order to reduce that risk, our HCWs stop any clustering noticed in the pantry/rubbish rooms in the hospital, and all patients/caregivers were asked to wear masks at all times, and to stay in the room unless special indication were noted. Furthermore, aerosol-generating procedures carry extra risk.¹¹ Inhalation therapy may spread viruses within about 6 feet and aerosols remain suspended in the air for prolonged periods.¹² All inhaled medications were restricted after the outbreak.

Table 2 Characteristics of confirmed cases.

	HCWs (n = 3)	Patients (n = 12)	Caregivers (n = 12)	Total (n = 27)
Demographics				
Age				
>60years	0 (0%)	11 (91.7%)	1 (8.3%)	12 (44.4%)
<60years	3 (100%)	1 (8.3%)	11 (91.7%)	15 (55.6%)
Sex				
Male	0 (0%)	9 (75.0%)	1 (8.3%)	10 (37.0%)
Female	3 (100%)	3 (25.0%)	11 (91.7%)	17 (63.0%)
Underlying illness				
Diabetes mellitus		4 (33.3%)		4 (14.8%)
Coronary artery disease/hypertension		7 (58.3%)	1 (8.3%)	8 (29.6%)
Lung cancer		2 (16.7%)		2 (7.4%)
Chronic kidney disease		3 (25.0%)		3 (11.1%)
Chronic lung disease		6 (50.0%)		6 (22.2%)
Presentation				
Fever/airway symptoms	0 (0%)	10 (83.3%)	7 (58.3%)	17 (63.0%)
Severity of COVID				
Mild	3 (100%)	1 (8.3%)	8 (66.7%)	12 (44.4%)
Moderate		3 (25.0%)	2 (16.7%)	5 (18.5%)
Severe		1 (8.3%)	2 (16.7%)	3 (11.1%)
Critical		7 (58.3%)		7 (25.9%)
Expired				
	0 (0%)	7 (58.3%)		7 (25.9%)

Many patients are completely bedridden in the index ward and their caretakers/companions play an important role in their daily care. However, caregivers can become problematic during the COVID epidemic. They are relatively healthier than patients and move around freely within the hospital. Because COVID may be asymptomatic, daily review of caregivers' symptoms is of little help. Case number 3 at FEMH was a caregiver in the index room. She was found to be COVID positive early in the investigation. Her history revealed that she had frequent chats with others, including the index case, and shared meals with other caregivers. In the context of COVID-19, these behaviors may readily spread the virus.¹³ Cases of COVID-positive caregivers were on par with that of patients in this outbreak. Screening of asymptomatic caregivers and avoiding contact between them are important measures to prevent the virus from spreading within the hospital.^{14,15}

In this event, most patients were older adults with underlying chronic conditions, while infected caregivers and HCWs were relatively young and had few symptoms. Person-to-person transmission may have occurred as a result of atypical presentations in the early stage.¹⁶ Infection transmitted by asymptomatic cases is one of the hallmarks of COVID-19 compared to SARS, and timely detection and management of asymptomatic patients are crucial.¹⁷ Similar to previous reports, COVID-19 is devastating to bedridden cases and the mortality rate exceeds 50%.^{18,19} During the outbreak at our hospital, treatment for COVID-19 was limited in Taiwan, and remdesivir was used only when the patient developed desaturation (Taiwan CDC Guidelines, 10th edition). Recent studies have shown that early remdesivir for treatment of infected cases, and monoclonal antibody for exposed individuals with risk factors for severe COVID helps to mitigate the high mortality.^{20,21} However, these options were not available at the early time of the pandemic.

The possibility of environmental contamination and infection transmitted through contaminated surfaces has been reported.²² However, in our environmental sampling, the virus was only detected on the door handle of the index room, which can be explained by several factors. First, we only do environmental sampling after cleaning. Thus, detecting the virus on the door handle may only reflect that it was the most heavily contaminated area or that the cleaning staff missed the spot repeatedly. Second, according to the transmission route we recreated, direct person-to-person transmission was expected to be the most important way of transmission.²³ Among all exposed HCWs, the three infected nurses (2 day-shift and 1 night-shift, with most treatment delivered during the day-shift) were the major service providers before the index case was diagnosed. Other healthcare workers, such as attending physicians, or nurses not serving this area, were not infected. However, a few cases were still detected outside the affected area. Whether they were infected due to personal contact or environmental contamination could not be determined.²⁴ In the statement of WHO, "despite consistent evidence as to SARS-CoV-2 contamination of surfaces and the survival of the virus on certain surfaces, there are no specific reports which have demonstrated fomite transmission." It is also difficult to distinguish infection caused by respiratory droplets or fomite.²⁵ Furthermore, this outbreak was caused by Alpha variant, which is associated with a lesser ability to cause transmission, compared to the current circulating Omicron variant, which is more contagious and may be spread by airborne transmission.²⁶

Vaccination is an important tool to protect HCWs. Before the surge in Taiwan, the willingness of HCWs to receive vaccination was relatively low (only Astra Zeneca vaccine was available at that time). The three infected nurses received their first dose of vaccination on May 14, which

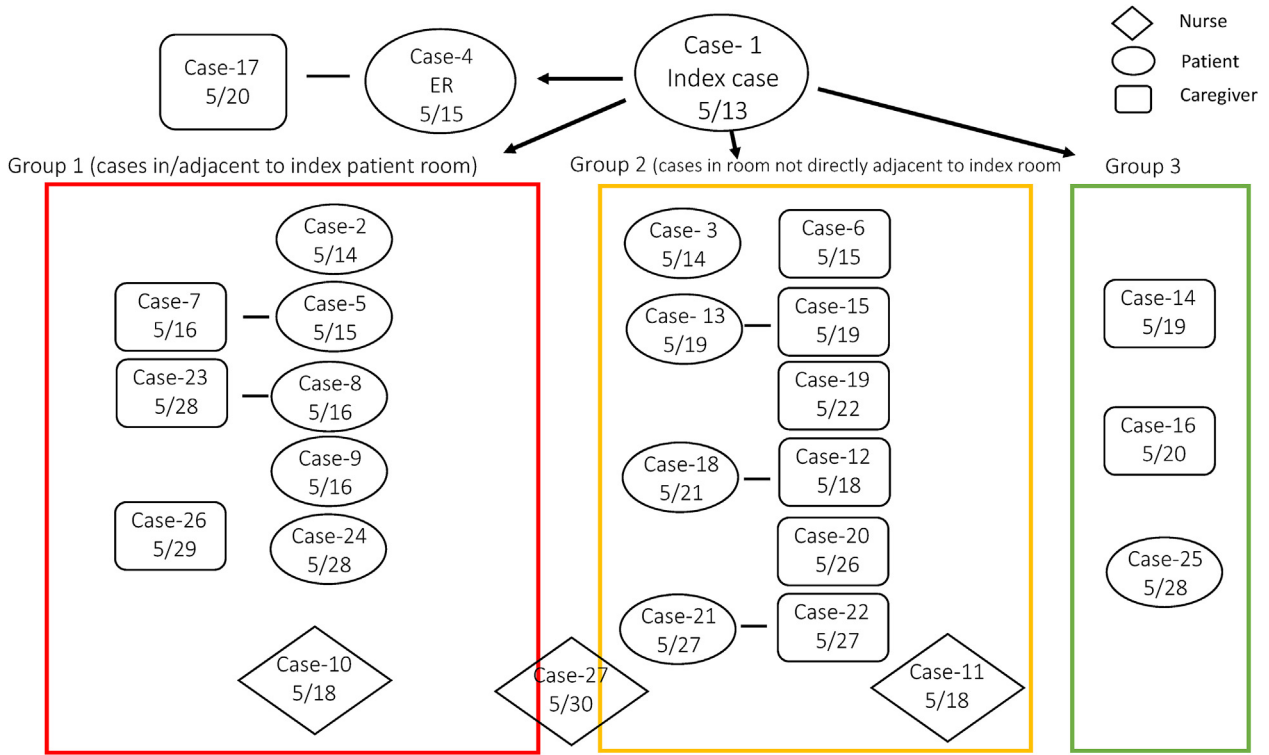


Figure 2. Temporal-spatial relationship among the index case and subsequent cases.

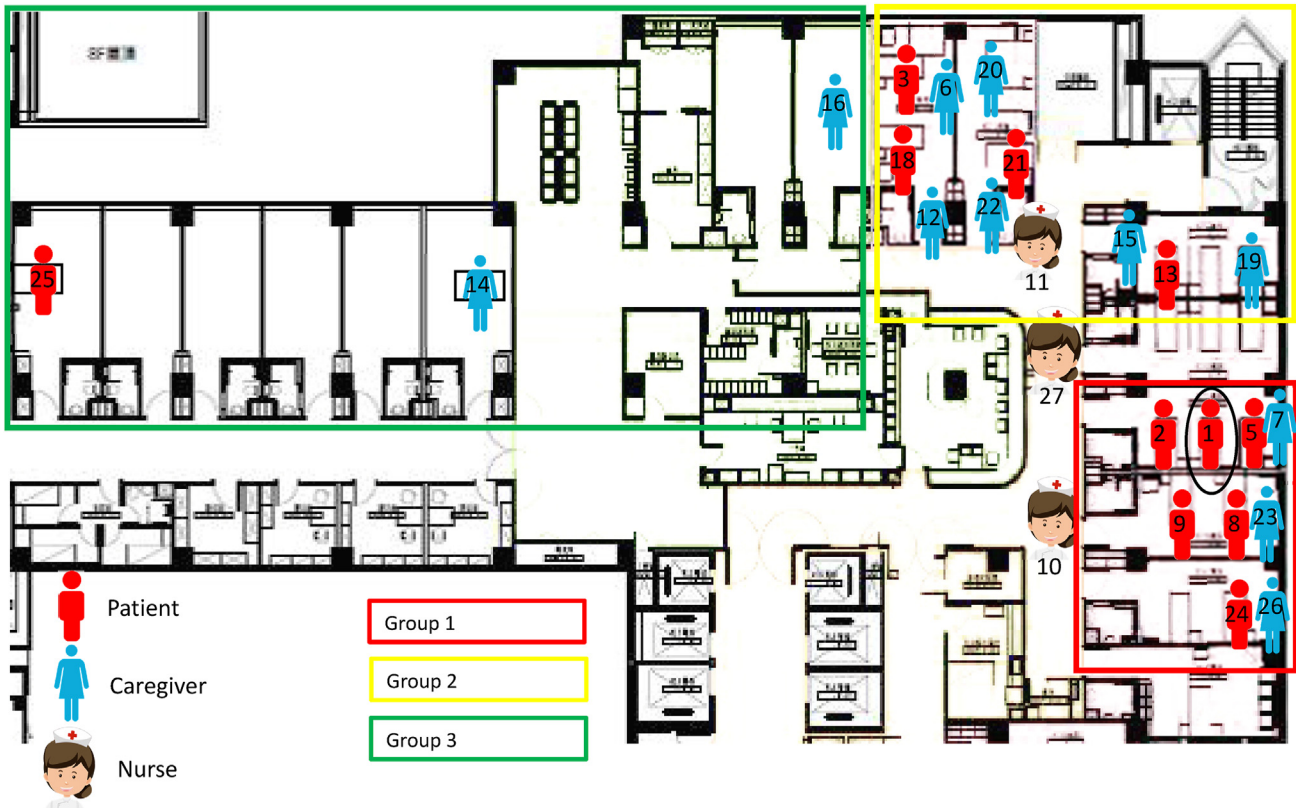


Figure 3. Layout of the index ward.

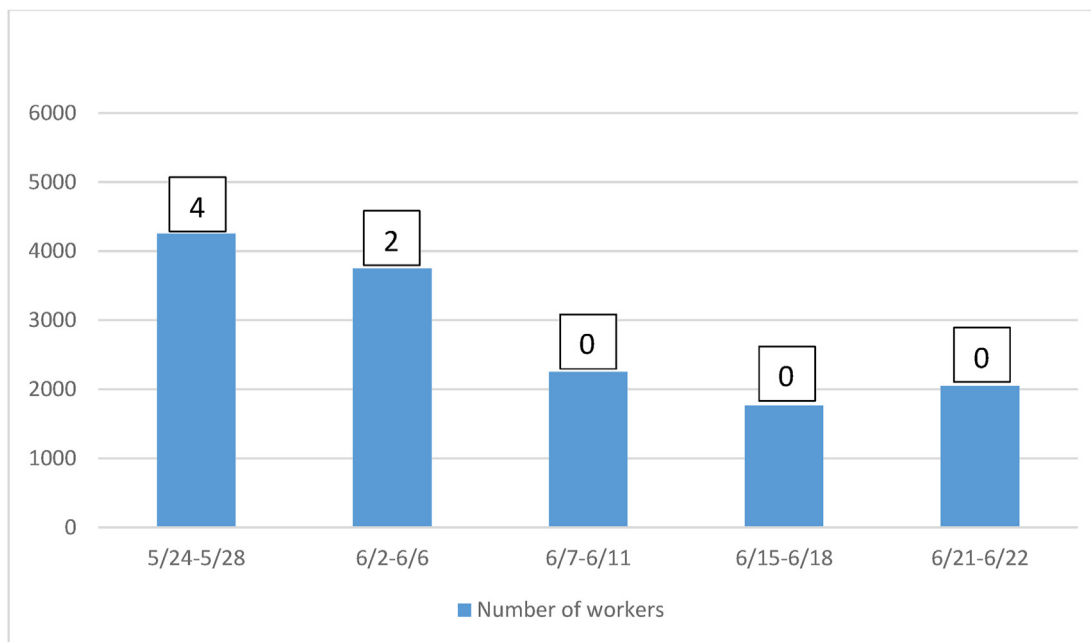


Figure 4. Hospital-wide PCR screening for healthcare workers (number of positive cases in squares).

	case	aerosol	Numbers of PCR testing and date of PCR positive																											
			13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30										
	1 (patient)	INH	*																											
	4 (patient)				1P																									
	17 (caregiver)										2P																			
Group1	2 (patient)			1P																										
	5 (patient)	AM			1P																									
	7 (caregiver)					1P																								
	8 (patient)	INH				1P																								
	23 (caregiver)																										4P			
	9 (patient)	TM					1P																							
	24 (patient)	INH																										4P		
26 (caregiver)																											4P			
10 (nurse)								2P																						
27 (nurse)																												4P		
Group2	3 (patient)	AM		1P																										
	6 (caregiver)				1P																									
	13 (patient)	AM								2P																				
	15 (caregiver)										3P																			
	18 (patient)											3P																		
	12 (caregiver)								2P																					
	21 (patient)	INH																									4P			
	22 (caregiver)																										3P			
19 (caregiver)														2P																
20 (caregiver)																											3P			
11 (nurse)								2P																						
Group3	14 (caregiver)								2P																					
	16 (caregiver)									2P																				
	25 (patient) +	INH																									4P			

Transmission pathways of group 1: person-person, aerosol and environmental transmission.

 Transmission pathways of group 2: person-person, visiting room

 Transmission pathways of group 3: person-person, dining room

Figure 5. Numbers of PCR testing and route of transmission.

definitely did not have the possibility of providing any meaningful protection. After the outbreak, the vaccination rate increased markedly. Moreover, hospital-wide PCR screening for HCW had detected several cases and prevented possible subsequent outbreaks. The importance of hospital-wide efforts has been discussed in a recent review,

and the hurdle for hospital-wide PCR is the maximal capacity of PCR tests in the hospital.²⁷ The lab had to test both clinical and surveillance samples. We overcame the difficulties by using pooled saliva samples, which does not cause discomfort for HCWs and increases the willingness of HCWs to cooperate with the hospital screening policy.²⁸

Limitations

This study has several limitations. This is a single-center descriptive analysis and therefore it is not possible to determine which measure was most effective. Also, the results of this evaluation cannot be generalized to other medical centers. Based on our experience, every intervention is important, because the possibility of transmitting the COVID-19 virus is particularly high. Second, we did not perform sequencing of the virus. However, we relied on government data showing that all of the virus circulating in May 2021 was Alpha variant. Third, we did not perform environmental sampling before cleaning, which might have been able to identify possible contaminated areas.

Conclusion

In this single-center experience of outbreak management, person-to-person transmission was considered to be most important transmission route. Exposure time is the major risk factor for HCW infection. Applying prompt infection control measures and large-scale PCR screening can control an outbreak of COVID-19 within 2 weeks.

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